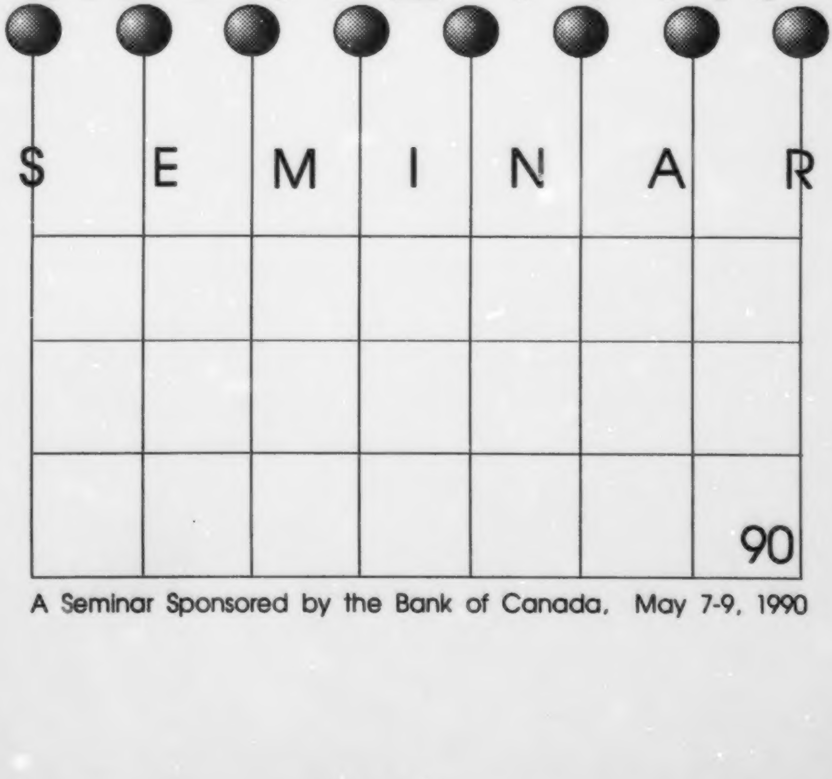
MONETARY



SEMINAR

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Introduction

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by David Longworth

The use of the monetary aggregates in the conduct of monetary policy has been of great interest to the Bank of Canada over the past twenty years. The heyday of the aggregates was from 1975 to 1981 when the Bank had formal targets for M1. Although no aggregate has subsequently proved robust enough to be adopted as a formal target, the Bank has continued to pursue an active research program to determine the usefulness of various monetary and credit aggregates in the policy process.

The two major avenues of research have involved the demand for money and the use of monetary and credit variables as leading indicators of inflation and economic activity. In the last four years, the Bank has published some major studies in both of these areas. Francesco Caramazza, Doug Hostland and Steve Poloz (1990) described the policy process and the demand for M2, while Kim McPhail and Caramazza (1990) estimated equations in growth-rate form for M2 and M2+. Earlier, Hostland, Poloz and Paul Storer (1988) had examined various monetary aggregates as leading indicators of inflation and spending, while Leslie Milton (1988) had done the same for various credit aggregates.

As a result of this research program, the monetary aggregates M2 and M2+ were shown to have certain desirable properties. For example, demand functions for these aggregates were more or less stable, they were among the best leading indicators of inflation, and their year-over-year growth rates were highly correlated with those of nominal spending. Because of these attributes, Governor John Crow was able to say in the Hanson Lecture in January 1988 that we "view M2 and M2+ ... as indicative policy guides."[1]

To provide a forum to critique the research done by the Bank on the monetary aggregates and to provide an incentive for Canada's academic community to pursue research on similar topics, the Bank decided in mid-1989 to sponsor a monetary seminar. A planning meeting took place in December 1989 with the authors of the six major papers and with David Laidler, Pierre Fortin and Charles Freedman to provide useful advice. The seminar itself took place May 7-9, 1990 at the Bank of Canada.

The seminar involved six papers, with one paper by a member of the Bank staff and one paper by an academic on each of three topics: (i) the demand for M2 and M2+ with special emphasis on cointegration; (ii) indicator models of inflation and spending; and (iii) a reconciliation of the reduced-form indicator models and money-demand equations with structural models.

Demand for money (M2 and M2+)

The paper by Francesco Caramazza, Doug Hostland and Kim McPhail reports the results of three separate studies of the demand for M2 and M2+. In the first, demand is modelled in growth-rate form with Almon lags using monthly data. The second approach analyzes the long-run demand for money in the context of quarterly error-correction models. The third study examines the demand for the major components of M2: currency, personal-sector deposits and non-personal-sector deposits. The findings include the following: (i) long-run price homogeneity is often not rejected; (ii) the net interest elasticity of the broad aggregates is close to zero; (iii) Canada Savings Bond (CSB) sales affect the aggregates, but CSB redemptions do not; (iv) there is some evidence of a downward shift in money demand in the 1983-84 period; and (v) there is little support for cointegration of M2 or M2+ with the usual explanatory variables.

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[1] J. Crow, "The work of Canadian monetary policy." Eric J. Hanson Memorial Lecture, *Bank of Canada Review*. (February 1988): 3-17.

The question of cointegration in the monthly demand functions for M2 and M2+ is pursued further in the paper by Steve Ambler and Alain Paquet. They conclude that, although there are unit roots in both M2 and M2+ velocities, both measures are stationary around a time trend that has a break after January 1983. With such a time trend, one cannot reject the hypothesis that the real income elasticity is one.

Indicator models

Building on earlier work at the Bank on single-equation indicator models, which explain output growth and inflation in terms of their lagged values and movements in financial variables, Patrice Muller asks whether financial aggregates are good sources of information. He concludes that they are. Further, he notes that indicator models that use lagged values on a single financial aggregate and no other financial variables, tend to yield better forecasts than more complicated models. He demonstrates that M1 expressed in real terms by deflating by the CPI is the best predictor of real GDP growth, while M2 and consumer bank credit are the best predictors of inflation. Muller shows that indicator-model forecasts anticipate revisions to national accounts data and add information to some of the publicly available macroeconomic forecasts.

Daniel Racette and Jacques Raynauld also seek to find whether monetary aggregates (base money, M1 and M2-M1) are useful in forecasting, but in the context of a Bayesian vector-autoregressive model of the Canadian economy. This model contains seven Canadian variables and five U.S. or international variables. Estimation and simulation of the model confirm that monetary aggregates do play a role in the determination of prices and nominal spending. However, this role is at times weak in comparison with that played by key U.S. or international variables. Overall, the model performs well over the 1980-87 period relative to a simple autoregressive model.

Reconciliation

Allan Crawford examines the type of money-demand equations estimated in the first session and the type of indicator models in Patrice Muller's paper (second session) to discover what they tell us about the major structural relationships for Canada. In terms of the demand for M2, he shows that the empirically longer lags on real income than on prices could result from a theoretical specification containing both permanent income and partial adjustment. In terms of the presence of lagged M2 in indicator models, Crawford argues that it can arise as a consequence of an interest rate reaction function for controlling the growth of money. While in theory money could also be acting as a proxy for liquidity constraints on spending, empirical results showing that money remains significant when various measures of credit are added to the equation cast doubt on this interpretation.

Allan Gregory, Gregor Smith and Tony Wirjanto examine a wide range of questions regarding what the money-demand and indicator models tell us about the transmission mechanism by examining simple theoretical structures (data-generating processes (DGPs)) under various assumptions about measurement, and about which variables are exogenous. Under the assumption that the nominal interest rate is exogenous, they show that for lagged money to enter the indicator model for output when there are realistic dynamics in the money-demand equation, the errors in the data-generating process for money and in the DGP for output must be negatively correlated, and the lagged error in the DGP for money and the error in the DGP for output must be positively correlated. The authors conclude that the traditional central bank view of the transmission mechanisms, as well as a wide variety of other structures, may be consistent with the dynamics of money-demand and indicator models.

Round Table discussion

In the Round Table discussion at the end of the seminar, Peter Howitt, Pierre Fortin and Charles Freedman summarized the results of the papers, discussed what further research would be useful, and examined the policy implications of the results.

Peter Howitt called for more theoretical work on microfoundations, the implications of rational expectations and the money supply process. He noted that the indicator model results undermine the presumption that money-demand residuals should be accommodated by policy and argued that perhaps more attention should be paid to M1.

Pierre Fortin suggested more work on the nature of the break in the demand for M2 in 1983, the role of wealth and rate-of-return differentials in the demand for M2, the nature and stability of the demand for M1, the refinement of Bayesian vector-autoregressive models, and identification of structural macroeconomic models. On the policy front, he suggested that the papers do not support a return to targeting the money stock. Further, the BVAR approach should be examined for use in policy analysis and forecasting. Finally, central bankers should continue to look at a wide range of information, to act cautiously and stay flexible in light of financial innovations and demand shifts.

Charles Freedman noted that it was very important to have a "consistent and integrated approach" to the interpretation of money and credit aggregates that would encompass the role of both demand and indicator models. He placed some emphasis on the possibility that nonlinearities might be useful in the reconciliation of the two types of models, while arguing that the disequilibrium money story is not likely to be helpful.

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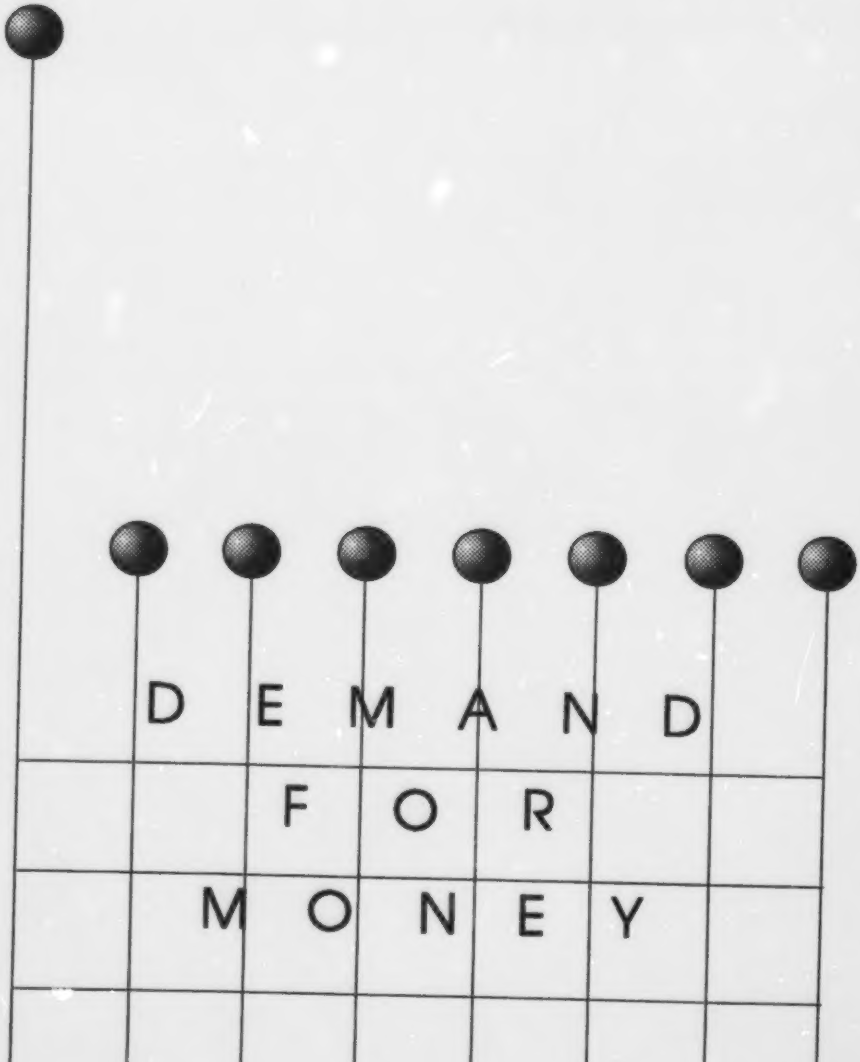

DEMAND FOR MONEY

STUDIES ON THE DEMAND FOR M2 AND M2+ IN CANADA

**by Francesco Caramazza, Doug Hostland
and Kim McPhail***

Introduction and Summary

This paper reports the results of three research projects carried out recently at the Bank of Canada on the demand for the broad monetary aggregates M2 and M2+.[1] Interest in the broad monetary aggregates increased after target ranges for M1 were abandoned in November 1981. In the 1970s, M1 had been considered the most reliable indicator of changes in total spending. However, in the late 1970s and early 1980s, the fairly tight and stable relationship between M1, total spending and short-term interest rates began to deteriorate as a result of increasing innovations in the financial services industry. As households and firms took advantage of the new ways of managing transactions balances offered by financial institutions, M1 became a less reliable guide for policy. In response, research was widened to the monetary aggregates with broad enough coverage to internalize the shifts between types of deposits that occurred as a result of financial innovation.

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[1] M2 consists of currency and demand deposits net of private-sector payments in transit, all personal notice and fixed-term deposits and non-personal notice deposits at chartered banks. The aggregate M2+ adds to M2 private-sector deposits at trust and mortgage loan companies, credit unions and *caisses populaires*.

* *The authors wish to thank numerous colleagues at the Bank of Canada for their comments on earlier drafts.*

That research involved both conventional summation monetary aggregates and superlative (Divisia) aggregates.[2]

Nonetheless, for several reasons, including the issue of structural stability and the questionable dynamic properties of traditional money-demand equations, it was felt that none of the aggregates examined could serve the demanding role of a policy target. The monetary aggregates do, however, provide useful information on the course of nominal spending, real output and inflation, as research on the information content of alternative monetary aggregates by Cockerline and Murray (1981), Hostland, Poloz and Storer (1988) and Muller (1989) has demonstrated.

A full description of recent research on indicator models of money and credit may be found in the paper by Muller in this volume. Here, we merely note that among the monetary aggregates, the growth of M2 is the best leading indicator of inflation and the growth of M2+ is one of the best contemporaneous indicators of the growth of nominal income. In view of these results and the relative stability of these aggregates, our research on money demand has concentrated on the M2 and M2+ aggregates.

A major issue in the modelling of money demand is the question of dynamics. Previous research has focussed mainly on level specifications using simple partial-adjustment dynamics. Estimates of the parameter on the lagged dependent variable in models of this form were generally found to be quite large - typically around 0.9 in monthly regressions, implying that after a year only about one-half of the adjustment was complete. This result is not unique for Canada but is found to be the case for most monetary aggregates in different countries and for various sample periods. Interpreting this finding in terms of dynamic adjustment behaviour at the individual level leads one to conclude that the implied speed of adjustment is implausibly slow. This stylized fact has been rationalized on a number of theoretical and statistical grounds, none of which, however, has led to the emergence of a completely satisfactory model for the demand for money. Although an explanation of the dynamics in money-demand functions is important for the interpretation of demand-for-money regressions, our aim here is to explore the implications of alternative approaches to the modelling of those dynamics. A review of alternative interpretations of demand-for-money regressions may be found in Caramazza, Hostland and Poloz (1990).

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[2] On the superlative aggregates, see Cockerline and Murray (1981).

Because of our concern with sensible short-run dynamic adjustment, we began our investigations of money demand (summarized in Section 2) by modelling the demand for M2 and M2+ in growth-rate form with Almon lags using monthly data.[3] This differs from the traditional partial-adjustment levels specification in two respects. One, it assumes that the error term in the demand equation is nonstationary and two, it frees up the dynamics by allowing money balances to adjust to changes in the explanatory variables at different speeds. The implied dynamic adjustment behaviour was found to be quite rapid: individuals adjust fully to price, real income and interest rate shocks within a year. This suggests that modelling the error in the demand for M2 and M2+ as a random walk process (at least approximately) may be useful for identifying money-demand dynamics over the short run. Furthermore, one might expect that the key to understanding the complete dynamics of money demand would lie in correctly specifying the long-run demand-for-money function. Consequently, we extended our investigations to the modelling of such a function.

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[3] Various versions of monthly growth-rate equations for M2 and M2+ have been used at the Bank for some time. Results for the version described in this paper were previously reported in "Technical note: The demand for M2 and M2+ in Canada," *Bank of Canada Review*, December 1989. Those results were the outcome of research that had been carried out by various members of the Bank's Department of Monetary and Financial Analysis.

Section 3 examines the long-run demand for M2 and M2+ using quarterly data. One objective here is to discover whether we can discriminate between alternative formulations of the long-run demand for M2 and M2+. This entails determining whether random shocks to the demand for M2 and M2+ have permanent effects (as implied by the growth-rate specification) or are better characterized as having transitory effects on the level of M2 and M2+ (in which case, levels specifications are appropriate for modelling the dynamics of M2 and M2+). A second objective is to examine the implications for the dynamics of money demand of alternative long-run specifications of the demand-for-money function.

Our analysis of the long-run demand-for-money function uses a different framework than that employed in Section 2. Instead of using Almon lag structures to capture monthly dynamics, we examine quarterly error-correction models. The error-correction parameterization is convenient for our purposes since it nests the different statistical methodologies that will be used to make inferences about the long-run money-demand function. In attempting to discriminate among alternative specifications of the long-run demand for M2 and M2+, we focus on whether we can isolate a cointegrating relationship underlying the demand-for-money function. Much of the analysis in this section centres on the statistical evidence for the cointegration hypothesis. We also consider long-run specification issues such as the statistical validity of long-run price homogeneity, the role of a deterministic trend component in velocity and the possibility that there have been discrete breaks in the trend velocity function. This leads to an examination of the implications of alternative models of the long-run demand for M2 and M2+ for the estimated short-run dynamic properties.

In our recent money-demand investigations, we also wanted to determine whether a disaggregated approach to money demand can enhance our understanding of movements in broad money in Canada and, in particular, whether it supports the findings concerning the properties of the long-run aggregate demand-for-money function derived from aggregate equations. Thus, Section 4 provides an examination of three distinct components of M2, namely, currency, personal-sector deposits (personal M2) and non-personal-sector deposits (non-personal M2). The methodology is similar to that used in Section 3, although specification searches were performed in a somewhat different fashion and a wider set of explanatory variables, suggested by previous research, was employed.

A number of conclusions emerge from these three investigations. In general, we found it difficult to discriminate among alternative long-run money-demand specifications, although a strong role for income and prices comes through clearly. The difficulty may be due to the low power of the available statistical techniques and to the paucity of degrees of freedom. Alternative models give different long-run income elasticities, ranging from 0.4 to 1.3 for M2 and from 0.5 to 1.5 for M2+, depending on whether the equation is estimated in growth-rate form and on whether a linear time trend is included in the specification (or a drift term in the growth-rate equations). However, the disparities are not as large as may initially appear. First, the long-run income elasticity derived from the disaggregated model is very similar to that obtained in the error-correction model for aggregate M2 which excludes the time trend: 1.4 compared to 1.3. Second, the steady-state properties of the latter model are quite similar to those of the growth-rate model; this occurs likely because the time trend is a proxy for a part of permanent income or wealth. The evidence concerning long-run price homogeneity is somewhat mixed. In general, the homogeneity restriction cannot be rejected under the assumption of a unit root, but it is rejected in the error-correction models - a rejection that we interpret as evidence of misspecification.

The net interest elasticity of M2 and M2+ is close to zero. The 90-day commercial paper rate, the proxy for the opportunity cost of holding non-interest-bearing deposits and currency is, in general, insignificant in the aggregate M2 and M2+ equations. However, the opportunity cost of holding interest-bearing deposits, proxied by the differential between the yield on 90-day commercial paper (R90) and the interest rate on 90-day fixed-term deposits at banks (B90), does help explain short-run movements in M2 and M2+. Although B90 serves as a good proxy for the own rate on deposits for the 1970s and most of the 1980s, there is some concern that it may not have been as appropriate in recent years. The yield on an investor account - a tiered daily interest savings account (DISA) introduced in 1985 - which, for the highest tier, is very close to that on treasury bills, may at present be a more representative measure of the own rate of return on personal savings deposits. A constructed own-rate series (ROWN) which includes the interest rate on high-balance DISAs is found to perform better than B90 in the last few years.

A proxy for the differential between interest rates on deposits at banks and at near-banks - the differential between the interest rate on 90-day fixed-term deposits at banks and the corresponding rate at trust and mortgage loan companies (B90 - T90) - is also found to explain movements in M2 growth in the monthly equations. This result, however, does not appear to be robust to alternative specifications. It finds some additional support in the personal M2 equation, but does not carry through in the error-correction models for aggregate M2. The net interest elasticity for personal M2 is, not surprisingly, positive, but larger than the scope for substitution out of currency and into deposits in response to a rise in interest rates would lead one to expect. For currency and non-personal deposits, the net interest rate elasticities are negative - of the order of -0.3 and -0.2, respectively, for the preferred equations.

One of the appealing features of modelling the demand for M2 and M2+ is that their coverage is broad enough to internalize the shifts between types of deposits caused by financial innovations. However, this broader coverage presents some issues concerning substitutability that do not arise in the modelling of narrow aggregates such as M1. One of these is the substitutability between deposits at banks and near-banks. Another is the substitutability between personal savings deposits and Canada Savings Bonds (CSBs). CSBs appear to be close substitutes for M2 and M2+ across all specifications. In addition, there is evidence, in the monthly growth-rate equations, that the effect of CSBs on M2 and M2+ is not symmetric: CSB sales affect M2 and M2+, whereas CSB redemptions do not.

A possible explanation for this is that it is the more sophisticated investors who substitute out of CSBs when increases in interest rates make CSBs a relatively less attractive investment. The substitution seems to be mainly into treasury bills. Thus, CSB redemptions result in only a short-lived inflow of funds into deposits included in M2 and M2+. Indeed, in all periods of unusually large redemptions of CSBs, the net change in households' combined holdings of CSBs and treasury bills has been very small. During the CSB sales period, however, the funds for purchases of CSBs come mostly from personal savings deposits; on balance, households do not appear to reduce their holdings of treasury bills in order to purchase CSBs.

In 1983 and 1984, the ratio of M2 and M2+ to nominal GDP declined markedly. This decline coincides with an apparent structural shift in the monthly money-demand equations specified in growth-rate form. One explanation attributes the behaviour of M2 and M2+ during this period to a reduction in intermediation as households used their liquid assets to pay down their debts in the post-recession period. This explanation, however, has been difficult to verify empirically. In the monthly M2 and M2+ growth-rate specifications, we deal with the apparent downward shift in money demand by including a dummy variable, which we refer to as the "consolidation-period" shift variable. This variable finds mixed support in the other specifications. It is significant in the quarterly error-correction models for M2 and M2+, but is not supported by the results of the static regressions. In the personal M2 equation, it is insignificant in specifications that include the earnings-price ratio (to represent the substitution between personal savings deposits and equity). Given the mixed results and the pre-test bias involved in the selection of the consolidation-shift variable, a definitive explanation of the behaviour of M2 and M2+ during the period in question cannot be offered at this time.

As already noted, the monthly growth-rate specifications imply much faster speeds of adjustment to changes in prices, income and interest rates than those typically found in conventional partial-adjustment formulations based on a levels specification. The error-correction models indicate, however, that more rapid adjustment speeds can also be obtained by freeing up the constraints on the dynamics imposed by partial-adjustment models. We estimate error-correction models that imply slightly faster rates of adjustment of money balances to price shocks than those suggested by growth-rate models. Modelling the error term in the demand for M2 and M2+ as a unit root process does not, therefore, necessarily result in quicker dynamics. Furthermore, the implied adjustment of M2 and M2+ to income shocks is more sensitive to whether or not the unit root hypothesis is maintained than the adjustment to price shocks.

The growth-rate models have much more rapid rates of adjustment to real income shocks than do the error-correction models, but a smaller long-run effect. Our estimates indicate that in the growth-rate specifications, M2 and M2+ adjust to price and income shocks at roughly similar speeds, whereas in the error-correction models, the adjustment to a price shock is about twice as fast as to an income shock. The difference in the adjustments of M2 and M2+ to real income shocks in the alternative money-demand specifications is perhaps not surprising given the different estimated long-run income elasticities. In the growth-rate specifications, a larger part of the permanent-income effect is reflected in the constant term, whereas in the error-correction models it is reflected in longer lags.

Finally, one of the principal conclusions to emerge from the analysis of the long-run demand for money is the difficulty in finding statistical evidence for cointegration. The cointegration tests provide scant support for the hypothesis that M2 and M2+ and the explanatory variables included in the long-run demand function are cointegrated. Consequently, we are unable to reject the hypothesis implied in the growth-rate specifications that the error term in the demand for M2 and M2+ has a unit root.

As noted above, the alternative money-demand specifications considered in this paper have different dynamic properties. The implication of this for policy depends on the role assigned to the monetary aggregates in the policy process. If M2 or M2+ were to be used as a multi-period intermediate target, the choice of money-demand function would have important implications for the conduct of policy over the targeting period. In particular, whether or not the error term is stationary would be very important. If money-demand shocks are viewed as permanent, it would be appropriate to allow money to deviate from its targeted growth path. On the other hand, if money-demand shocks are seen as transitory, it would be more appropriate to resist deviations of money from its targeted level, with bands around the target that reflect the persistence of the velocity shocks.[4] However, if, as is the case today, the monetary aggregates are not used as targets but rather serve, *inter alia,* to provide timely information about the strength of nominal spending growth in, say, the current quarter or the upcoming quarter, then there is little difference in the information implied by the alternative money-demand specifications described above.

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[4] Friedman and Kuttner (1989) find that U.S. M2 and income are not cointegrated and conclude that "Even if monetary policy were to be conducted in terms of [intermediate] targets for money growth, the failure of money and income to be co-integrated [sic] means that there is no empirical ground for resisting the 'base drift' that results from persistent random differences between actual money growth and the corresponding target."

A number of issues raised here have not been fully resolved and require further research. Among these are the construction of a more satisfactory proxy for the own rate of return on broad money, the application of more powerful cointegration tests that are currently being developed in the expectation that these will enable us to make stronger inferences regarding cointegrating relationships and the long-run demand for M2 and M2+, and the implications of alternative measures of permanent income (or wealth) for the adjustment of M2 and M2+ to income shocks. Research on these topics may also clarify other issues, such as the behaviour of the velocity of M2 and M2+ in 1983 and 1984 and the finding of a positive, albeit small, net interest elasticity for personal-sector deposits. However, it would appear that a portfolio model with a richer institutional structure is required to resolve more satisfactorily such issues as the nature of the substitution among personal savings deposits, treasury bills and CSBs, and the substitution between M2 and the "plus" component of M2+, that is, shifts in the share of total deposits held by banks and near-banks.

Before turning to the empirical estimates, we present a very brief overview of the literature on the demand for broad money in Canada and of the major financial innovations that have influenced the monetary aggregates.

1. An Overview

1.1 The literature

The typical model found in the empirical literature on the demand for broad money in Canada assumes that the long-run desired level of real balances is a function of real income or wealth and a vector of interest rates, and that money balances adjust gradually to a change in the explanatory variables. The equation is generally specified in log form, but in some cases the level, rather than the log, of the interest rate is used. Some studies (Boughton, 1981; Clark, 1973; Cockerline, 1979; Cockerline and Murray, 1981; Laumas and Formuzis, 1968; and Ram, 1982) assume that the adjustment of nominal balances to a change in prices is instantaneous, whereas others (Cameron, 1979; Clinton, 1973; Foot, 1977; Rausser and Laumas, 1976; and White, 1976) allow for gradual adjustment, but impose a long-run unitary price elasticity. In some studies, dynamic effects are modelled by means of a Koyck-type adjustment (Boughton, Clinton, Cockerline, Foot), while in others, an Almon distributed-lag structure is used (Cameron, White). The opportunity cost of holding money is frequently represented by a single, competing market rate of interest; however, Cameron, Clinton, Cockerline, and Foot include a measure of the own rate of return on deposits. The latter is typically approximated by a weighted average of the components of the monetary aggregate studied. Boughton and Ram, in addition, include the rate of inflation as an explanatory variable.

By and large, the findings of these studies are similar. With the exception of Clark and certain sample periods considered by White, the estimated long-run income elasticity is close to unity and the interest rate has a negative and statistically significant effect on the demand for broad money. White, however, finds the interest rate to be both economically and statistically insignificant. Studies that include an own rate on deposits find that it enters the demand equation with the expected positive sign.

The stability of the demand for broad money has been evaluated in several ways: by examining the ordinary or recursive residuals, by Chow tests or by estimating varying-parameter models. Most studies report some evidence of instability. Boughton and Ram, nevertheless, cannot reject the hypothesis of no structural break in the demand for M2.

Finally, it should be noted that, for the most part, the published empirical literature does not cover the 1980s. The sample period thus excludes a period of rapid financial innovation and a shift in economic environment from one of rising and high inflation in the 1960s and 1970s to one of lower inflation in the 1980s.

1.2 Financial innovation and the monetary aggregates

Since the mid-1970s, financial innovation in Canada has been entirely the result of changes in the market environment rather than a response to financial deregulation of the type that has occurred in the United States and other countries.[5] That is, innovations have resulted from the interaction of high interest rates and inflation rates in the late 1970s and early 1980s, advances in information technology and competition among financial institutions. Consequently, the effects of the innovations on the monetary aggregates have tended to be continuous and gradual.

Financial innovation has affected both the household and corporate sectors. There were two main periods of financial innovation affecting corporations. The first was in the mid-1970s when banks started offering sophisticated cash management services to large firms and large governmental organizations. The second occurred in the early 1980s when smaller-sized firms began to use these services and banks began to offer companies interest-bearing chequable accounts. The result was a reduction in firms' transactions balances and a shift of funds from current accounts into non-personal notice deposits, a component of M2.

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[5] For a detailed description of financial innovation in Canada see Freedman (1983) and Fine (1990, in this volume).

The first major innovation to affect the deposits of households was the introduction in 1979 of daily interest savings accounts or DISAs.[6] Since DISAs could not generally be used for transactions purposes, most of the funds deposited in these accounts were transferred from other forms of savings accounts. Nevertheless, DISAs provided an additional incentive for households to economize on their holdings of transactions balances,[7] thus reducing the demand for personal chequing accounts and hence the demand for M1. The second major innovation to have important implications for the behaviour of the monetary aggregates was the widespread introduction in 1981 of daily interest chequable savings accounts (DICAs).[8] These accounts combine features of both the daily interest savings account and the personal chequing account. The daily interest chequable savings account is classified as a "notice" deposit and is included in M2, but not in M1.[9] The growth of these deposits has been very rapid, but appears to have come largely at the expense of other personal savings deposits.

The most recent innovation in retail banking was the introduction in 1985, and the widespread adoption in late 1987, of tiered investor accounts. These are DISAs that pay progressively higher interest rates on higher balances. The yields on the highest tranches are comparable to the yield on treasury bills. Although chequing privileges are offered, these accounts are not generally suitable as transactions accounts and are classified as non-chequable personal savings deposits. Most of the funds for these accounts seem to have come from other DISAs, personal fixed-term deposits and DICAs, so that the shifts were largely internal to M2+ and M2. Some of the funds going into these deposits, however, may have come from CSBs and money market instruments.

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[6] DISAs had been offered by the Bank of British Columbia and some credit unions since the mid-1960s, but their rapid growth began with nationwide introduction by the major banks in 1979.

[7] This gained in importance as banks reduced and eventually eliminated withdrawal fees and as automated banking machines (ABMs) were introduced.

[8] DICAs had been available on a more limited basis since 1977.

[9] The aggregate M1A, consisting of M1 plus DICAs and non-personal notice deposits, was monitored for a time, but it proved to be influenced more by innovations than M1 - see Figure 1.

The evolution of the monetary aggregates is illustrated in Figures 1 to 5. The M1 component of M2 has declined from 36 per cent in 1969 to 17 per cent in 1989, with the greatest decline occurring in the 1975-82 period (Figure 1). Since the major part of M1 does not pay interest,[10] another way of expressing this development is that the interest-earning component of M2 has risen from about two-thirds to over four-fifths in the past two decades.

The ratio of M2+ to nominal GDP has followed a rising trend since the early 1970s (Figure 2). The ratio of M2 to nominal GDP showed no discernible trend up to 1978, but rose quite sharply from 1979 to 1982, declined steeply in 1983 and 1984, and subsequently resumed its upward trend. Over the past two decades, trend growth of M2+ has exceeded that of M2, especially in the 1970s, reflecting the more rapid growth of deposits at near-banks than at banks. The proportion of M2 in M2+ declined from about 70 per cent in 1969 to 58 1/2 per cent in 1989 (Figure 3). Substitution between M2 and the "plus" component of M2+ may thus be an important element to consider in the modelling of the demand for M2.

The above discussion suggests another point. Although the demand for M2 and M2+ may be expected to exhibit less variability than the demand for M1 because these aggregates internalize the shifts in funds that have affected M1, the behaviour of M2 and M2+ velocity in the 1980s suggests that these

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[10] At the end of 1989, only 22 per cent of demand deposits (including interbank deposits that are excluded from M1) were interest-bearing. The proportion of interest-bearing deposits in M1 was thus between 11 per cent (if all interbank deposits pay interest) and 25 per cent (if none of the interbank demand deposits pay interest).

Figure 1
M1 and M1A as a Proportion of M2

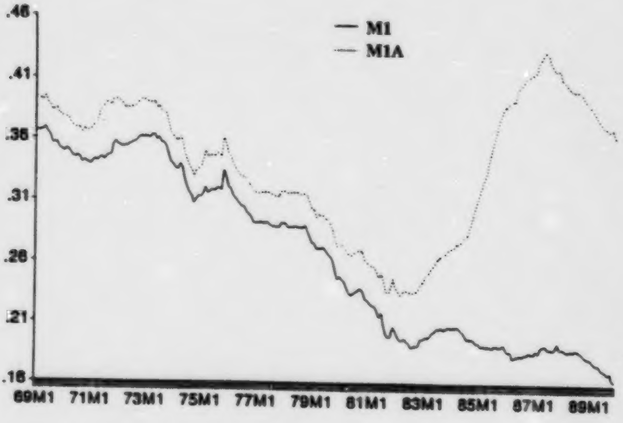


Figure 2
Ratio of M2 and M2+ to Nominal GDP

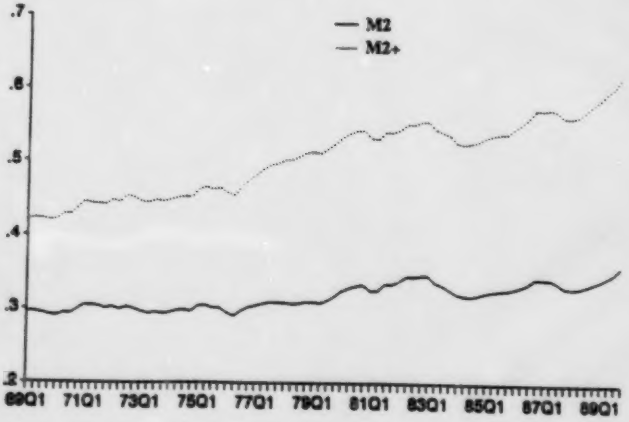
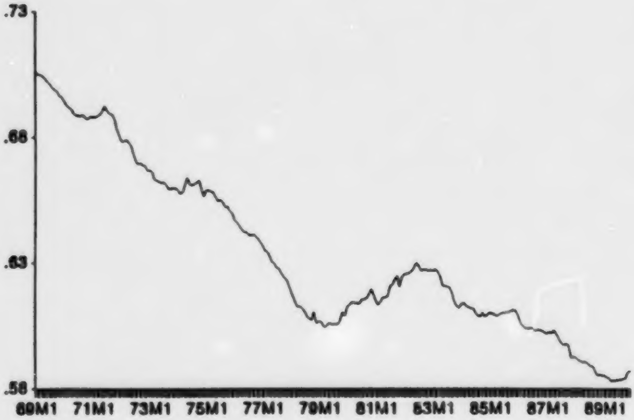


Figure 3
M2 as a Proportion of M2+



aggregates have been subject to influences other than portfolio substitutions associated with financial innovation. In particular, an explanation of the behaviour of velocity in 1983-1984 could be significant for any consideration of the stability of demand for M2.

Figures 4 and 5 show the evolution of M2 and M2+ growth rates. The dashed lines plot the annualized monthly growth rates and the solid lines show the underlying trends, as represented by the 12-month growth rates.

2. Monthly M2 and M2+ Equations

Partial-adjustment formulations of the demand for money found in the literature typically report implausibly slow speeds of adjustment of money balances to changes in income and interest rates. A possible explanation of

Figure 4
Growth of M2

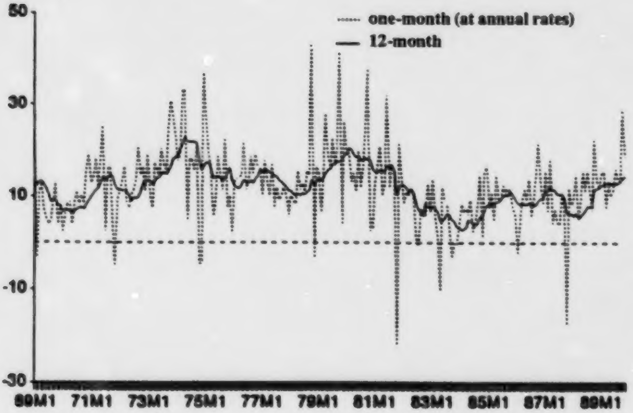
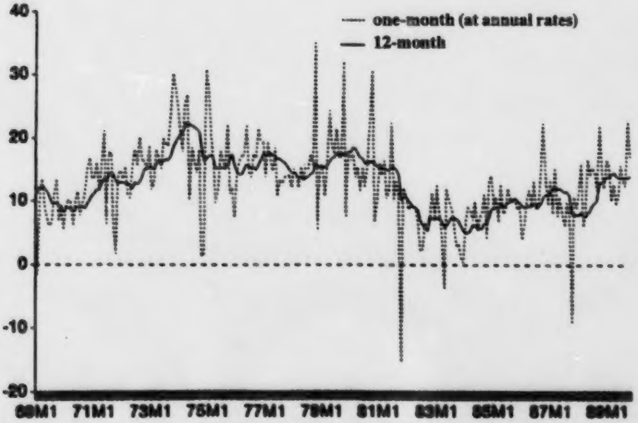


Figure 5
Growth of M2+



this result is that the errors in the estimated demand function are nonstationary. In the event, an equation estimated in first differences, which would render the errors stationary, could result in more credible adjustment dynamics. In this section we report the results of monthly equations for M2 and M2+ estimated in first differences of logarithms. Stationarity issues are taken up in the next section. Our focus here is on two issues: the substitution between M2 and M2+ and other financial assets, and the substitution between M2 and the "plus" component of M2+.

The major portion of deposits in M2 and M2+ are interest-bearing. Hence, the opportunity cost of holding these deposits is the differential between the own rate of return and competing market rates. Deposit rates usually follow market rates of interest, but the two are not perfectly correlated so that, at the margin, movements in the differential may significantly affect the growth of M2 and M2+ in the short run. Interest rates on various types of personal savings deposits were tried as proxies for the own rate of interest on M2 and M2+. The rate that gives the best results - in terms of the lowest standard error of the regression - is the rate on 90-day fixed-term deposits at banks.[11]

We proxy the competing market rate of interest by the 90-day commercial paper rate. Rates of return on a number of other assets were also tried, but the estimated coefficients were often insignificant. This finding does not necessarily imply a lack of substitution between deposits at banks and near-banks and other assets. Inasmuch as rates of return on interest-bearing assets tend to be highly correlated, it is difficult to isolate the influence of each asset return independently on the demand for M2 and M2+. The 90-day commercial paper rate, therefore, may not capture fully the substitution between M2 and M2+ and other financial assets held by households. An alternative way to account for substitution when it is very high, is to enter the stocks of assets directly in the money-demand equation. Although this procedure is not generally appropriate, it may be so for CSBs because the effect of the CSB interest rate on the demand for M2 and M2+ is not symmetrical. CSBs can generally be redeemed at any time, but they can only be purchased once a year. Since CSBs can be redeemed before maturity without penalty, they can be used to hedge against future increases in interest rates. This feature gives CSBs an option value that makes it difficult to measure their rate of return accurately relative to personal savings deposits. In view of these considerations, the value of the outstanding stock of CSBs is used to capture the substitution between personal savings deposits and CSBs. Stocks of other financial assets were also considered, but they were found to be insignificant.[12]

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[11] As discussed below, in recent years this rate may have become less appropriate because of the introduction of high-balance DISAs.

In modelling the demand for M2 and M2+ it is also necessary to take into account the fact that the public can allocate funds not only between deposits and other financial instruments, but also between deposits at banks and deposits at near-banks - the "plus" component of M2+. Variations in the differential between interest rates offered by banks and those offered by near-banks on similar deposits may be expected to be an important factor in explaining short-run movements in M2. The competing rate on deposits at near-banks is proxied by the interest rate on 90-day fixed-term deposits at trust and mortgage loan companies (TMLs).

The 90-day rates on commercial paper, fixed-term deposits at banks and at TMLs and their differentials, are plotted in Figures 6 to 8.

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[12] A more complete description of the various measures that were used in attempts to model the substitution between M2 and M2+ and other financial assets may be found in McPhail and Caramazza (1990).

Figure 6
Interest Rate on 90-Day Commercial Paper (R90), 90-Day Fixed-Term Deposits at Banks (B90) and TMLs (T90)

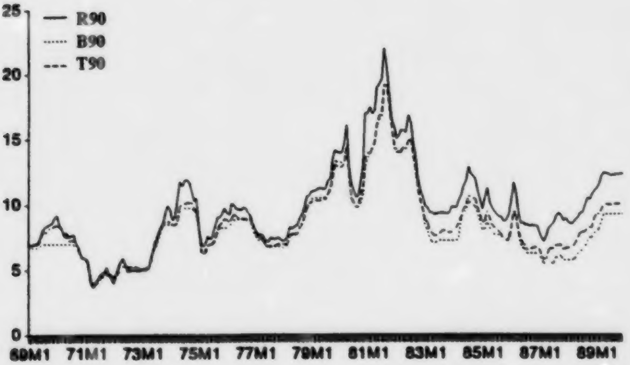


Figure 7
(R90 - B90) and (R90 - ROWN)

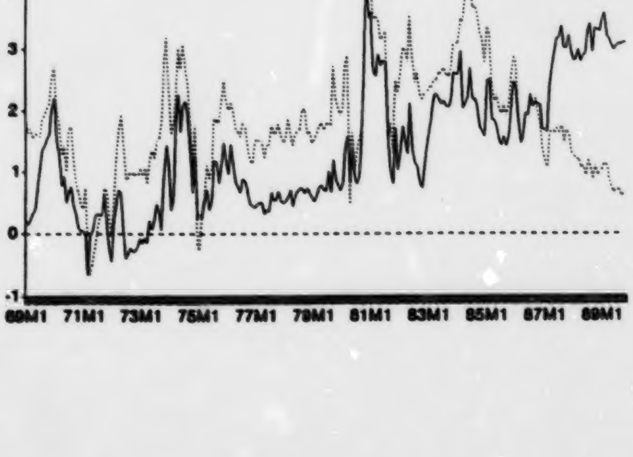
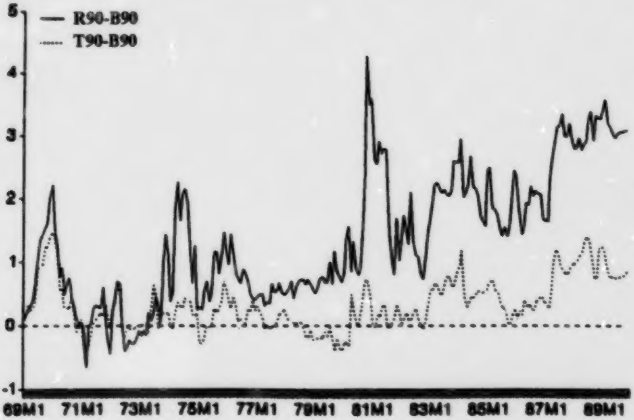


Figure 8
(R90 - B90) and (T90 - B90)



The following monthly money-demand equations serve as the starting point of our empirical investigation:

$$\begin{aligned}\Delta m2 = \; & A(0) + B(L)\,\Delta p + C(L)\,\Delta y + D(L)\,\Delta R90 \\ & + E(L)\,\Delta(R90 - B90) + F(L)\,\Delta(B90 - T90) \\ & + G(0)\,\Delta csb \qquad (1)\end{aligned}$$

$$\begin{aligned}\Delta m2+ = \; & A(0) + B(L)\,\Delta p + C(L)\,\Delta y + D(L)\,\Delta R90 \\ & + E(L)\,\Delta(R90 - B90) + G(0)\,\Delta csb \qquad (2)\end{aligned}$$

where all variables except interest rates are in logarithms, p is the GDP deflator, y is real GDP, R90 is the 90-day commercial paper rate, B90 is the interest rate on 90-day fixed-term deposits at banks, T90 is the interest rate on 90-day fixed-term deposits at near-banks, and csb is the outstanding stock of CSBs divided by the GDP deflator.[13] Money balances are assumed to adjust gradually to a change in prices, real income or interest rates. Almon lags are used for these variables as a parsimonious way of reducing the multicollinearity among lagged values. Long-run price homogeneity is imposed by constraining the Almon lag coefficients on the price variable to sum to one.

Equations (1) and (2), with one modification, were estimated for the January 1970 - December 1987 period.[14] Results are reported in regression (1) in Tables 1 and 2.[15] The modification involves the inclusion of a vector of dummy variables to account for the temporary increases in the money stock during postal strikes in 1974, 1975, 1978, and 1981,[16] and for the unusual reduction in the level of M2 and M2+ in May 1983. Qualitatively similar results were obtained when equations (1) and (2), and their variants described below, were estimated using strike-adjusted data instead of postal strike dummies, and when the May 1983 dummy variable is omitted.[17]

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[13] Data sources and definitions for all variables used in the paper are given in Appendix 1.

[14] Except for a minor difference in parameterization and re-estimation with a more recent data set, these equations are the same as those reported in the December 1989 *Bank of Canada Review* article "Technical note: The demand for M2 and M2+ in Canada." The data base was as of February 1990.

[15] Tables 1 and 2 report only the long-run properties of the estimated equations. A complete description of regression (2) is given in Appendix 2.

[16] For an analysis of the effect of postal strikes on the demand for M1 see Gregory and MacKinnon (1980).

[17] All data are monthly except prices, for which interpolated monthly values of the quarterly GDP deflator are used. Almost identical results are obtained when monthly estimates of the GDP deflator derived by Kozicki (1989), using a procedure similar to that of Guay et al. (1988), are employed. Preliminary testing has shown that the demand for M2 and M2+ is better related to the GDP deflator than to the CPI, which is available monthly.

Prices, real income, interest rates, and CSBs explain about two-thirds of the variance in the monthly growth of M2 and M2+. All coefficients have the expected sign and are statistically significant at the 5 per cent level or lower. The long-run income elasticities of 0.51 for M2 and 0.68 for M2+ are lower than those typically found for broad monetary aggregates. One interpretation of this result is that these elasticities measure the effect on M2 and M2+ of cyclical variations in real income about its underlying trend, while the trend in real income is reflected in the constant term.[18] Because of the constant term alone, M2 and M2+ would grow at an annual rate of 3.5 per cent.[19]

The net interest rate (semi-) elasticities are negative, but close to zero, as one would expect for monetary aggregates that are predominantly interest-bearing. Of course, the responsiveness of M2 and M2+ to individual interest rate changes is much larger than that to generalized changes. The former effects, however, would be relevant only over the very short run, since market forces would prevent sustained large increases in interest differentials on competing financial assets.

CSBs and M2 and M2+ do appear to be close substitutes. The elasticity of M2 with respect to CSBs is -0.12 and that of M2+ is -0.09. These elasticities imply that at 1989 levels, a $1 increase in the stock of CSBs would reduce M2 balances by $0.54 and M2+ balances by $0.67. That CSBs should have such a large influence on the broad monetary aggregates is perhaps not surprising. The effect on M2 and M2+ of unusually small or unusually large

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[18] It is recalled that since the equations estimate the change in the logarithm of the levels of M2 and M2+, the constant term corresponds to the coefficient on a linear time trend in equations estimating the logarithm of levels of M2 and M2+. This is taken up again in Section 3.

[19] Various measures of real wealth - consisting of financial and physical assets - were included in the demand equations, but they generally did not contribute to the explanation of M2 and M2+ growth beyond that captured by real GDP. See McPhail and Caramazza (1990).

CSB sales in November of each year is clearly visible in the plot of the monthly growth rates in Figures 4 and 5.

As can be seen in Figures 2 and 3, between 1982 and 1984 there was a steep decline in the ratio of M2 and M2+ to nominal GDP. A rolling Chow test indicated a structural shift in the demand for M2 and M2+ in late 1982. One possible explanation of this shift is that the high level of interest rates in the early 1980s and the uncertainties engendered by the 1981-82 recession induced households to consolidate their financial positions by scaling down both their assets and liabilities. To account for this shift, we have included in the M2 and M2+ equations, after examining the residuals, a variable that takes the value of one between 1982:07 and 1984:11 and zero in other months. The results reported in regression (2) of Tables 1 and 2, imply a cumulative downward shift of 6.7 per cent ($9.8 billion) in M2 balances in November 1984 and of 7.9 per cent ($19 billion) in M2+ balances. Since we have been unable to explain this shift empirically by means of economic variables alone, and since the inclusion of the consolidation-period dummy does not alter the properties of the estimated demand equations in any important sense, we have kept the "consolidation dummy" in the equations in the hope that future research will clarify the behaviour of M2 and M2+ velocity between 1982 and 1984. We return to this issue in the next section in the context of unit root tests and in Section 4 in the context of modelling the demand for personal-sector deposits.

Equations (1) and (2) assume that changes in the stock of CSBs during the CSB sales and redemption periods have symmetrical effects on the demand for M2 and M2+. This need not be the case. As noted earlier, casual evidence suggests that it is the more sophisticated investors who substitute out of CSBs when increases in interest rates make CSBs a relatively less attractive investment. This substitution seems to be mainly into treasury bills. Thus, CSB redemptions result in only a short-lived inflow of funds into

Table 1
M2 Monthly Growth-Rate Equation: Long-Run Properties
(1970:01-1987:12)

	Regression				
Variable	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
Constant	0.0029	0.0031	0.0032	0.0038	0.0032
	(5.994)	(6.556)	(7.048)	(3.798)	(3.263)
Prices	1.0	1.0	1.0	0.9080	1.0040
				(7.560)	(8.499)
Income	0.505	0.507	0.437	0.457	0.440
	(3.711)	(3.794)	(3.390)	(3.068)	(3.103)
R90	-0.0010	-0.0017	-0.0003	-0.0012	-0.0004
	(0.713)	(1.236)	(0.271)	(0.821)	(0.268)
R90-B90	-0.0126	-0.0115	-0.0087	-0.0114	-0.0087
	(2.416)	(2.228)	(1.763)	(2.193)	(1.758)
B90-T90	0.0418	0.0352	0.0308	0.0344	0.0308
	(3.649)	(3.062)	(2.816)	(2.972)	(2.803)
CSB	-0.1262	-0.1249		-0.1252	
	(13.775)	(13.849)		(13.855)	
DUM82-84		-0.0023	-0.0028	-0.0025	-0.0028
		(2.825)	(3.664)	(2.924)	(3.541)
CSB*DNOV			-0.1445		-0.1445
			(15.256)		(15.216)
CSB*DDEC			-0.0703		-0.0703
			(3.664)		(3.655)
CSB*(1-DNOV-DDEC)			-0.0093		-0.0090
			(0.147)		(0.251)
$\bar{R}^2$	0.658	0.670	0.704	0.669	0.702
S.E.E.(x10^2)	0.377	0.370	0.350	0.370	0.351
D.W.	1.967	2.010	2.048	2.015	2.048

Note: Absolute value of t-statistic in parentheses

Table 2
M2+ Monthly Growth-Rate Equation: Long-Run Properties (1970:01-1987:12)

	Regression				
Variable	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
Constant	0.0029	0.0033	0.0033	0.0050	0.0046
	(8.070)	(9.259)	(9.826)	(6.895)	(6.488)
Prices	1.0	1.0	1.0	0.7650	0.8204
				(8.801)	(9.451)
Income	0.683	0.681	0.630	0.554	0.543
	(6.562)	(6.880)	(6.549)	(5.121)	(5.214)
R90	-0.0019	-0.0027	-0.0016	-0.0016	-0.0010
	(2.033)	(2.918)	(1.718)	(1.653)	(1.038)
R90-B90	-0.0166	-0.0144	-0.0123	-0.0131	-0.0116
	(5.904)	(5.285)	(4.650)	(4.782)	(4.369)
CSB	-0.0932	-0.0920		-0.0927	
	(13.359)	(13.852)		(14.171)	
DUM82-84		-0.0027	-0.0030	-0.0031	-0.0033
		(4.618)	(5.364)	(5.248)	(5.748)
CSB*DNOV			-0.1061		-0.1059
			(15.021)		(15.108)
CSB*DDEC			-0.0549		-0.0541
			(3.588)		(3.854)
CSB*(1-DNOV-DDEC)			-0.0092		-0.0242
			(0.362)		(0.918)
$\bar{R}^2$	0.651	0.683	0.712	0.693	0.717
S.E.E. (X10^2)	0.289	0.275	0.262	0.271	0.260
D.W.	1.454	1.571	1.578	1.613	1.608

Note: Absolute value of t-statistic in parentheses deposits included in M2 and M2+. In fact, in years in which there have been unusually large CSB redemptions, M2 and M2+ have not grown significantly faster in those redemption periods than during the rest of the year. Moreover, in all such instances, the net change in households' combined holdings of CSBs and treasury bills has been very small.[20] During the CSB sales period, however, the funds for purchases of CSBs come mostly from personal savings deposits; on balance, households do not appear to reduce their holdings of treasury bills in order to purchase CSBs.

To test for asymmetrical CSB effects, equations (1) and (2) were re-estimated to allow for different effects during CSB sale and redemption periods - that is, the coefficient on the CSB variable was allowed to take different values for the months January to October (the redemption period), for November and for December[21] :

$$\begin{aligned} \Delta m2 = {} & A(0) + B(L)\,\Delta p + C(L)\,\Delta y + D(L)\,\Delta R90 \\ & + E(L)\,\Delta(R90 - B90) + F(L)\,\Delta(B90 - T90) \\ & + G(0)\,\Delta csb{*}DNOV + H(0)\,\Delta csb{*}DDEC \\ & + I(0)\,\Delta csb{*}(1\text{-}DNOV\text{-}DDEC) \end{aligned} \tag{1'}$$

$$\begin{aligned} \Delta m2+ = {} & A(0) + B(L)\,\Delta p + C(L)\,\Delta y + D(L)\,\Delta R90 \\ & + E(L)\,\Delta(R90 - B90) + G(0)\,\Delta csb{*}DNOV \\ & + H(0)\,\Delta csb{*}DDEC + I(0) \\ & \Delta csb{*}(1\text{-}DNOV\text{-}DDEC) \end{aligned} \tag{2'}$$

where DNOV is a dummy variable equal to 1 in November and 0 in other months, and DDEC is a dummy variable equal to 1 in December and 0 in other months.[22,23] The results indicate that changes in the stock of CSBs have asymmetrical effects on M2 and M2+ growth. Indeed, only CSB sales have an effect, redemptions have no effect. About two-thirds of the effect occurs in November and one-third in December.[24] The possibility that the effect of CSB redemptions on the demand for M2 and M2+ is nonlinear - that is, that it varies with the size of redemptions, was tested and rejected.[25] Neither average-sized nor unusually large redemptions seem to influence the growth of M2 and M2+.

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[20] See "Monetary aggregates in Canada: Some recent developments," *Bank of Canada Review*, February 1990.

[21] This section draws on research conducted by Patrice Muller.

The equations discussed thus far have been estimated with the long-run price elasticity constrained to unity. An F-test cannot reject the constraint at the 5 per cent level for the M2 equation and at the 1 per cent level for the asymmetric CSB specification of the M2+ equation. Unconstrained estimates are reported in columns (4) and (5) of Tables 1 and 2.

The dynamics of regressions (1) and (2) with respect to income and prices are presented in Table 3. The speed of adjustment of M2 and M2+ to price and income shocks implied by these equations is much faster than that found in partial-adjustment formulations of the demand for broad money. Approximately 80 per cent of the adjustment of M2+ to a price shock or to a real income shock occurs within 6 months, while the corresponding adjustment of M2 is 70 per cent to a price shock and 78 per cent to a real

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[22] Dummy variables to test for shifts in the intercept were also included; they were statistically insignificant.

[23] For most of the sample period, the CSB campaign ended in the second week of November. Since we use average-of-month data, the stock of CSBs in December will be higher than in November and the effect of changes in CSBs on M2 and M2+ growth will be spread over November and December. It is necessary, therefore, to include dummy variables for both November and December.

[24] These results hold when seasonally unadjusted data are used for all variables and the seasonality is captured by seasonal dummies.

[25] This was done by including in equations (1') and (2') threshold redemption rates or, alternatively, the square of CSB redemptions. None of these variables was significant.

income shock. Full adjustment is achieved in one year. The adjustment of M2 and M2+ to a change in interest rates is also quite rapid. Complete adjustment to a change in deposit rates and in the yield on competing non-deposit financial assets occurs in 9 months, while the adjustment of deposits among financial institutions is somewhat slower (16 months). The latter result may reflect the fact that the demand for deposits is a joint demand for a savings instrument and the services provided by banks and near-banks. Since shopping for similar bundles of savings instruments and customer services is costly, depositors may be reluctant to switch from one financial institution to another in response to modest, and presumably fairly short-lived, interest rate differentials.

Table 3
Effect of a One Per Cent Permanent Increase in the Price Level and in the Level of Real Income on the Levels of M2 and M2+

	Effect on M2 of shock to:		Effect on M2+ of shock to:	
Month	Prices	Real income	Prices	Real income
1	0.076	0.119 (23.5)	0.161	0.130 (19.0)
2	0.186	0.209 (41.2)	0.316	0.244 (35.8)
3	0.316	0.276 (54.4)	0.459	0.343 (50.3)
4	0.452	0.326 (64.3)	0.589	0.427 (62.7)
5	0.583	0.365 (71.9)	0.701	0.497 (73.0)
6	0.703	0.396 (78.0)	0.795	0.554 (81.3)
7	0.805	0.422 (83.1)	0.869	0.599 (87.9)
8	0.885	0.445 (87.6)	0.925	0.632 (92.7)
9	0.942	0.465 (91.7)	0.963	0.655 (96.2)
10	0.978	0.484 (95.3)	0.986	0.670 (98.4)
11	0.995	0.499 (98.2)	0.997	0.678 (99.6)
12	1.000	0.507 (100)	1.000	0.681 (100)

Note: Numbers in parentheses give proportion of adjustment completed.

To conclude this section we return to the question of the own rate of return of M2 and M2+. In the regressions reported in Tables 1 and 2, the own rate has been proxied by the interest rate on 90-day fixed-term deposits at chartered banks. While this variable seems appropriate for the 1970s and the first half or so of the 1980s, it may be less appropriate for recent years because of the introduction and rapid growth, especially since 1987, of high-balance DISAs.[26] Thus, the effective marginal opportunity cost of holding M2 and M2+ balances may be better represented by the differential between R90 and the highest prevailing yield on personal savings deposits than by the differential between R90 and B90.

In an attempt to better measure the own rate of return on M2 and M2+, we have constructed an interest rate series that gradually incorporates the yield on the new types of deposits introduced in the 1980s. This alternative own-rate series is given by:

$$\mathrm{ROWN} = \max[\mathrm{RSDB}, \mathrm{RT}]$$

and

$$\mathrm{RT} = \mathrm{RH} + w[\mathrm{RH}^{*} - \mathrm{RH}]$$

where ROWN is a "learning-adjusted" yield on personal savings deposits,[27] RSDB is the interest rate on non-chequable personal savings deposits at banks, RH* is the rate on the prevailing highest-yielding DICA/DISA deposit, and RH is the rate on the previous highest-yielding DICA/DISA deposit. RT allows depositors to adapt gradually to new types of deposits, with the speed of adaptation, or "learning" given by w. We assume that in the first month, when a new higher-yielding type of deposit is introduced, w = 0.2, in the second month w = 0.4, and so on. The assumed speed of adaptation is arbitrary and serves to avoid jumps in the constructed own-rate series.

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[26] See Section 1.2 on financial innovations.

[27] ROWN is based on interest rates at chartered banks. Data availability has so far prevented the computation of an own-rate series for near-banks.

The differential between R90 and ROWN is plotted in Figure 7 together with the differential between R90 and B90. As can be seen, the two series move in a similar manner up to the end of 1986, after which they diverge considerably. The reason is that until the early 1980s, ROWN corresponds to RSDB, which is highly correlated with B90, whereas starting in 1987, ROWN corresponds to the yield on high-balance DISAs.

When the M2 and M2+ equations are re-estimated for the 1970:01-1987:12 period, with B90 replaced by ROWN,[28] the results are not much different. The net interest elasticities are even closer to zero, with the elasticities for (R90 - ROWN) about half the size of those of (R90 - B90). Moreover, the proportion of the variance of M2 and M2+ growth explained by the specification with the alternative own-rate measure is somewhat smaller. However, when the sample is extended to 1989:12, the S.E.E. of the regressions with B90 rise, whereas the S.E.E. of the regressions with ROWN declines. These results tentatively suggest that in the post-1987 period, demand equations for broad money that incorporate the yield on high-balance DISAs are likely to capture more accurately the substitution at the margin between M2 and M2+ and competing financial assets. It should be noted, however, that although for recent years the differential between R90 and ROWN has been a better measure of the opportunity cost of holding M2 and M2+, it is not entirely satisfactory. One reason is that it does not take into consideration the fact that the return on treasury bills net of transactions costs has risen in the 1980s as those costs have fallen. The measurement of the own rate of return for broad money remains a topic for further research.

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[28] In the M2 equation, (B90-T90) is retained as the variable that represents the substitution between deposits at banks and at near-banks.

3. The Long-Run Demand for M2 and M2+

3.1 Two methodologies for identifying the long-run demand for M2 and M2+

Until recently, empirical research on the demand for money has been performed under the assumption that money and all the explanatory variables are stationary. The stationarity assumption enables researchers to use conventional statistical procedures for making inferences. Thus, specification issues regarding the long-run demand for money could be examined in a straightforward manner. However, recent developments in econometrics show that inferences based on conventional statistical procedures (i.e., standard normal asymptotic distribution theory) are invalid when regressions involve integrated regressors.[29] This greatly complicates the methodology by which researchers can best examine long-run specification issues, since appropriate statistical procedures for making valid inferences in regressions with integrated regressors are still at an early stage of development.

In view of this, we use two statistical methods to identify the long-run demand function for M2 and M2+. One methodology, which we will refer to as the "conventional approach," relies on conventional statistical procedures. The other, which we will refer to as the "cointegration approach," relies on unit root tests. Both methodologies can be described in the context of the following money-demand model expressed in error-correction form:

$$\Delta m = \alpha(L)\Delta m_{-1} + \beta(L)\Delta X - \delta(m_{-1} - \tau X_{-1}) + u \qquad (3)$$

where m is the nominal stock of money, X is a vector of weakly exogenous variables and u is a random error term. This error-correction model rests on the hypothesis that m and X are cointegrated, which implies that m and the variables in X are all first-order integrated processes (i.e., m and X are I(1)) and that the vector m - τX is a stationary process (i.e., m - τX is I(0)). The cointegration vector, m - τX, represents the long-run money-demand function, while the parameters $\alpha(L)$, $\beta(L)$ and δ, capture the dynamic adjustment of money balances around this long-run equilibrium.

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[29] See Phillips (1989).

An important result from cointegration theory is that the estimated short- and long-run parameters have quite different statistical properties. Stock (1987) shows that under the cointegration hypothesis, least-squares estimates of $\alpha(L)$, $\beta(L)$ and δ have standard normal limiting distributions, whereas least-squares estimates of τ have non-normal limiting distributions.[30] Consequently, conventional statistical tests cannot be used to make valid inferences about the long-run parameters, τ. Further, the distribution of the OLS estimate of δ has a non-normal distribution under the unit root hypothesis, H_0: $\delta = 0$, so that a conventional t-test on δ cannot be used to infer whether m - τX is I(0). Thus, cointegration theory suggests that conventional inference procedures may be misleading for identifying a long-run demand-for-money function that involves integrated variables.

An alternative approach is to make inferences on τ and δ based on their non-normal limiting distributions. The general difficulty with deriving asymptotic tests for δ (under the unit root hypothesis) is that its limiting distribution tends to depend on the other parameters in the model (i.e., its limiting distribution involves nuisance parameters). Hence, we have to simulate the distribution of δ for each model to test the cointegration hypothesis. Fortunately, cointegration tests that are relatively insensitive to nuisance parameters have been developed. Two such tests are the Augmented Dickey-Fuller (ADF) and the Phillips-Perron (PP) test for unit roots.[31] We use both the ADF and the PP tests for unit roots as a basis for model selection as follows.

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[30] West (1988) shows that the least-squares estimates of τ have a limiting normal distribution when X is I(1) with drift. The implication of West's result will be discussed below.

First, we determine the order of integration for all the variables in the model using the sequential testing procedure suggested by Perron (1988). This procedure isolates a set of variables with the same order of integration, a necessary condition for cointegration. For example, if real money balances are found to be a first-order integrated process (i.e., m - p is I(1)), then only variables that are first-order integrated processes should be considered as candidates for the cointegration vector. We then estimate alternative cointegration vectors using static regressions and perform unit root tests on the OLS residuals. A rejection of the unit root hypothesis is evidence that the variables in the static regression are cointegrated. According to this methodology, statistical evidence of cointegration is interpreted as having identified the long-run demand-for-money function.[32]

One of the disadvantages with cointegration tests is that they have low power when the root is close to the unit circle. This may make it difficult for us to discriminate among alternative specifications of the cointegration vector. Conventional statistical procedures may then be of some value for identifying the long-run money-demand function. The conventional model-specification methodology searches across alternative specifications of the long-run demand-for-money function, $m - \tau X$, and isolates variables in the vector X that are found to have statistically significant long-run elasticities. Although our inferences on τ obtained through conventional statistical procedures are

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31. For a discussion of the statistical theory underlying the ADF and PP tests see Engle and Granger (1987), Phillips and Perron (1988) and Perron (1988).

32. It is possible to identify more than one cointegration vector using this methodology. We avoid this potential problem by using the ADF and PP test statistics as a basis for model selection. This assumes implicitly the uniqueness of the cointegration vector. Johansen (1988) has developed a statistical procedure that would enable us to test the number of cointegration vectors in a system of equations. Perhaps this procedure could be used to test the validity of our uniqueness assumption.

technically invalid, this strategy may be reliable as a means of model identification if the bias involved in using the standard normal distribution as an approximation to the non-normal distribution is not too great.

3.2 Identifying the long-run demand for M2 and M2+

3.2.1 The cointegration approach

The objective of this approach is to determine whether there is statistical evidence to support the existence of a cointegration vector representing the long-run demand for M2 and M2+. Our analysis is conducted in the standard theoretical money-demand framework - real M2 and M2+ balances are determined by real income and their opportunity cost. Given the difficulty in adequately measuring the opportunity cost of holding M2 and M2+ balances, a number of proxies are used to measure this concept. In our analysis, we examine which proxies best define the long-run demand for M2 and M2+.

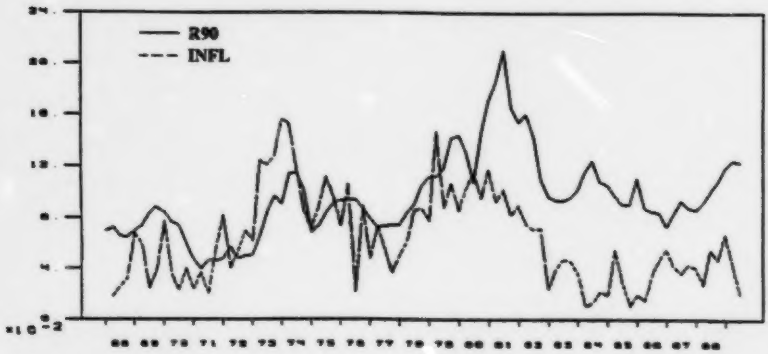
The monthly growth-rate equations presented in the previous section indicate that the stock of CSBs has an empirically important long-run effect on the demand for M2 and M2+. CSBs are regarded as close substitutes for personal savings deposits. Consequently, permanent changes in CSBs are expected to have some long-run effects on the level of M2 and M2+ balances. Given the difficulty in accurately measuring the relative rate of return on CSBs, we take the same approach as in the previous section by including the stock of CSBs (in real terms) in the M2 and M2+ equations to capture substitution between CSBs and personal savings deposits.

We also consider the possibility that there have been permanent shifts between M2 and M2+ deposits and other liquid financial assets. We try to capture this substitution by using the various proxies for the own and substitute rates of return described in the previous section - the rate of return on 90-day corporate paper (R90) is used to measure the substitute rate of return; the rate of return on 90-day personal fixed-term deposits at banks (B90), non-chequable savings deposits (RSDB) and the constructed series (ROWN) are used to measure the own rate of return of M2 and M2+ deposits.

Given the declining proportion of M2 relative to M2+ over the sample period (see Figure 4), there is the possibility that some of the increase in deposits held at near-banks may be due to substitution from deposits held at banks. As in the previous section, we attempt to capture this substitution by using the spread between 90-day personal fixed-term deposits at trust and mortgage loan companies (T90) and 90-day personal fixed-term deposits at banks (B90). The differential (T90 - B90) is intended to model market-share movements between M2 and the "plus" component of M2+ in the M2 equations.

As noted above, the first stage in the cointegration strategy is to determine the order of integration of each of the variables in the model. Hence, univariate time-series analysis of unit roots is performed using the sequential testing procedure suggested by Perron (1988). It is not possible to reject a unit root in the *level* of real M2, real M2+, real CSBs, and the price level using the ADF and PP (t, $\ddot{\alpha}$) test statistics, but it is possible to reject a unit root in the first difference of these variables. Thus, the ADF and PP tests indicate that real M2, real M2+, real CSBs, and the price level are all I(1). According to the unit root tests, the two bouts of inflation in the 1970s (shown in Figure 9) are viewed as transitory deviations from the steady state rather than as movements in the steady-state inflation rate. The nominal short-term interest rate is I(1), moving mostly in response to inflationary expectations in the 1970s and in response to a permanent increase in the level of real interest rates in the early 1980s (see R90 in Figure 9).

Figure 9
Nominal Interest Rate (R90) and Inflation (INFL)



Figures 7 and 8 and Figures 10 and 11 illustrate the rates of return on M2 deposits relative to alternative financial assets. The differentials between market rates (R90) and the rate of return on 90-day personal fixed-term deposits at banks (B90) and savings deposits (RSDB) have been trending upward throughout the sample period (Figures 10 and 11). Both of the differentials (R90 - B90) and (R90 - RSDB) are found to be trend-stationary. However, Figure 10 shows that the trend in (R90 - RSDB) is reversed in about 1984 when we consider the rate of return on tiered DISA accounts (ROWN) as the relevant rate of return on savings deposits. The differential (R90 - ROWN) is found to be mean-stationary. This suggests that the trends in (R90 - B90) and (R90 - RSDB) may be due to ongoing financial innovations throughout the sample period which are imperfectly measured.

Figure 10
The Relative Rate of Return of Savings Deposits

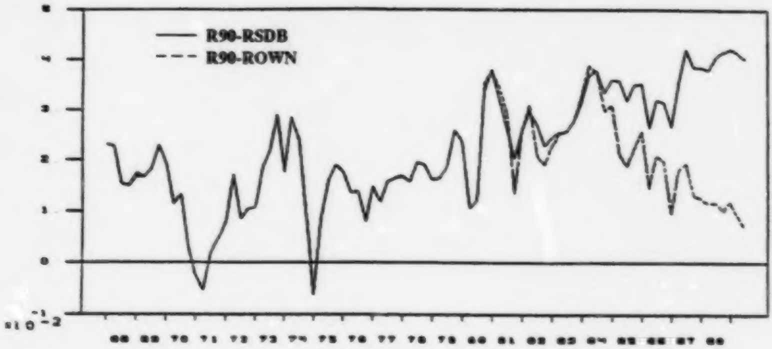
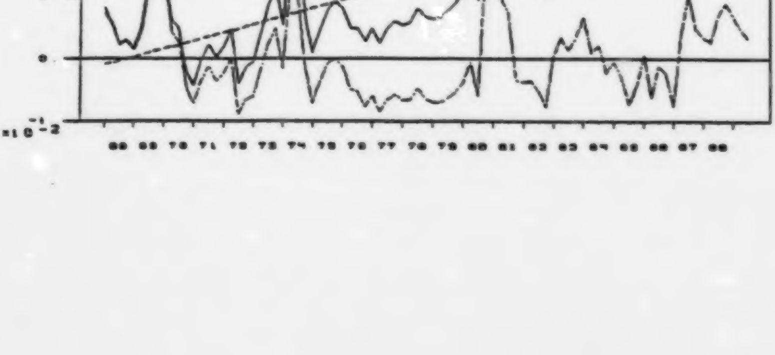


Figure 11
Detrended (R90 - B90)



For this reason, we detrended the interest rate differentials, (R90 - B90) and (R90 - RSDB) to make them stationary (illustrated in Figure 11 for (R90 - B90)). The trends in (R90 - B90) and (R90 - RSDB) are assumed to be due to measurement error, whereas the stationary component is used to proxy the opportunity cost of holding M2 and M2+ balances. This detrending procedure allows for *transitory* substitution between M2 and M2+ deposits and alternative financial assets but precludes the possibility that the trends in the interest rate differentials capture *permanent* substitution effects.

The differential between 90-day personal fixed-term deposits at trust and mortgage loan companies and at banks (T90 - B90) has not deviated far from zero until the past few years (Figure 8). This differential is found to be mean-stationary. This result should not be surprising given the high degree of substitutability between deposits held at banks and near-banks. However, since (T90 - B90) is I(0), it cannot account for *permanent* shifts in M2 and, hence, cannot explain the ongoing decline in the banks' market share of deposits observed over the sample period. A richer model of the institutional structure is no doubt required to explain the observed permanent shifts in market share between M2 deposits and the "plus" component of M2+.

Having determined the order of integration for each of the variables, we can now form hypotheses about which sets of variables represent valid cointegration vectors. To preserve degrees of freedom, it would first be useful to consider cointegration vectors with real, rather than nominal M2 and M2+ as the dependent variable. We will return to the issue of whether long-run price homogeneity is a valid restriction later on in this section. The univariate unit root tests indicated that real M2 and real M2+ are I(1) without drift. A necessary condition for cointegration is that the variables in the cointegration vector be at least I(1). Consequently, the interest rate differentials (R90 - B90), (R90 - RSDB), (R90 - ROWN), (T90 - B90), and inflation cannot be considered as potential candidates in the cointegration vector. We examine the possibility that real M2 and real M2+ are cointegrated with the variables that were found to be I(1): real income (y),[33] real CSBs (csb), and the level of short-term interest rates (R90).[34] We also consider the possibility that the cointegration vector involves a deterministic trend component by including a linear time trend (t) in the cointegration tests.

Cointegration tests are performed by first estimating static regressions and then applying the ADF and PP unit root tests to the OLS residuals. A rejection of a unit root in the residuals is evidence that the variables in the static regression are cointegrated. OLS estimates of alternative static regressions and the corresponding ADF and PP unit root test statistics are shown in Table 4. It is important to note that the power of the cointegration tests declines rather quickly when we add additional variables to the cointegration vector. For this reason, we restrict our analysis to cointegration vectors having a maximum of five variables (including the constant term).[35] For presentation purposes, we focus on a vector involving a constant term, real income and real CSBs as a benchmark and then show the implications of adding R90 and a linear time trend.

In addition to applying cointegration tests to OLS residuals from static regressions, we also apply cointegration tests to alternative estimates of the cointegration vector. Simulation experiments by Banerjee et al. (1986) indicate that OLS estimates of cointegration vectors from static regressions

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[33] In regressions reported in this section real final sales is used to measure real income. Previous research indicated that subtracting inventory movements from real GDP improved the properties of M2+ equations. The use of real final sales instead of real GDP, however, has little effect on the cointegration tests or on the qualitative results in this section.

[34] All lowercase variables represent logs; all interest rates are measured in levels.

[35] Five variables correspond to the maximum number of variables for which we have critical values for the test statistics.

Table 4
Tests for Cointegration (Sample: 1969Q1-1989Q3, 83 observations)

ADF and PP test statistics reported below along with the estimated adjustment parameter (δ) from error-correction models

	ADF	PP	δ	Log-likelihood
OLS estimates of static regressions for M2				
$m - p = 1.294y - 0.057csb$	2.77	2.72		
$m - p = 1.285y - 0.051csb + 0.039R90$	2.83	2.67		
$m - p = 0.691y - 0.100csb + 0.00597t$	4.29*	3.00		
$m - p = 0.718y - 0.134csb + 0.00617t - 0.216R90$	3.79	3.34		
NLS estimates from error-correction models for M2				
$m - p = 1.305y - 0.100csb$	2.47	2.47	0.094*	316.315
$m - p = 1.327y - 0.108csb - 0.195R90$	2.22	2.46	0.099*	316.680
$m - p = 0.752y - 0.104csb + 0.00532t$	4.25*	3.85	0.179*	317.822
$m - p = 0.773y - 0.113csb + 0.00530t - 0.123R90$	3.88	3.86	0.187*	318.145
OLS estimates of static regressions for M2+				
$m - p = 1.544y - 0.075csb$	2.88	3.27		
$m - p = 1.550y - 0.079csb - 0.024R90$	2.86	3.30		
$m - p = 1.157y - 0.103csb + 0.00384t$	3.10	3.11		
$m - p = 1.181y - 0.133csb + 0.00402t - 0.190R90$	2.93	3.36		
NLS estimates from error-corrections models for M2+				
$m - p = 1.509y - 0.091csb$	2.11	2.46	0.099*	333.361
$m - p = 1.563y - 0.100csb - 0.655R90$	1.77	2.52	0.098*	336.607
$m - p = 2.057y - 0.092csb - 0.00531t$	1.59	1.97	0.076	334.227
$m - p = 2.634y - 0.098csb - 0.01002t - 1.206R90$	1.46	2.03	0.060	338.344

Note: The ADF and PP cointegration tests examine the null hypothesis that the OLS residuals from the static regression have a unit root. A rejection of the unit root hypothesis is evidence that the variables in the static regression are cointegrated.

Critical values for the cointegration tests are based on simulation experiments for cointegrating regressions using 100 observations (taken from Table 2, p. 157 in Engle and Yoo, 1987).

* statistically significant at the 0.05 level

can be substantially biased in small samples.[36] More efficient estimates of the cointegration vector can be obtained by estimating the long-run elasticities and the short-run dynamics simultaneously. This one-step procedure is referred to in the cointegration literature as nonlinear least-squares (NLS) estimation.

The drawback of the NLS estimation procedure is that it requires specification of the dynamics and, hence, inferences with regard to the cointegration vector will be conditional to some extent on the modeller's judgment in specifying the model's dynamics. We attempt to minimize the effect of the dynamic specification on our inferences by using the same dynamic specification for the alternative specifications of the cointegration vector. The dynamics were modelled using a general-to-specific testing procedure. This involved first establishing the dynamic order of the system. After estimating alternative unrestricted autoregressive distributed-lag specifications of up to fourth order, the second-order dynamic specification was found to be the most appropriate according to sequential F-tests in the context of the most general model.

In the context of the second-order dynamic system for M2, the interest rate differential (T90 - B90) was found to be statistically insignificant and was excluded from the analysis. Three proxies for the relative rate of return on M2 and M2+ deposits were used: detrended (R90 - B90), detrended (R90 - RSDB) and (R90 - ROWN). Collinearity among these interest rate differentials makes it difficult to identify their separate effects. The differential (R90 - B90) is preferred on the basis of statistical criteria (i.e., the S.E.E.) to the other two differentials in M2 and M2+ regressions. Thus,

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[36] Banerjee et al. (1986) show that the bias is an increasing function of $(1 - R^2)$. Since the static regressions for real M2 and real M2+ have R^2s of over 0.995, this bias may be relatively small for our estimates.

(R90 - B90) alone is used to proxy the opportunity cost of holding interest-bearing M2 and M2+ deposits. The resulting unrestricted autoregressive distributed-lag specification can be represented by:

$$\begin{aligned}\alpha_m(L)m = {} & \alpha_0 + \alpha_t t + \alpha_p(L)p + \alpha_y(L)y + \tau_c(L)csb \\ & + \alpha_r(L)R90 + \alpha_{rd}(L)(R90\text{-}B90) + u \qquad (4)\end{aligned}$$

where $\alpha_i(L)$ represents a second-order polynomial operator on the lag structure for each variable i and u is a random error term. With simple algebraic manipulation, equation (4) can be expressed in error-correction form as follows:

$$\begin{aligned}\Delta m = {} & \alpha_0 + \alpha_m \Delta m_{-1} + \alpha_{p0}\Delta p + \alpha_{p1}\Delta p_{-1} + \alpha_{y0}\Delta y \\ & + \alpha_{y1}\Delta y_{-1} + \alpha_{c0}\Delta csb + \alpha_{c1}\Delta csb_{-1} \\ & + \alpha_{r0}\Delta R90 + \alpha_{r1}\Delta R90_{-1} + \alpha_{rd0}(R90 - B90) \\ & + \alpha_{rd1}(R90_{-1} - B90_{-1}) + \alpha_{rd2}(R90_{-2} - B90_{-2}) \\ & - \delta(\, m_{-2} - p_{-2} - \tau_y y_{-2} - \tau_c csb_{-2} - \tau_r R90_{-2} - \tau_t t) + u \qquad (5)\end{aligned}$$

where the α parameters represent short-run elasticities, the τ parameters are the long-run elasticities and δ represents the error-correction adjustment parameter. Note that the autoregressive distributed-lag specification (4) and the error-correction representation (5) are statistically equivalent. The error-correction parameterization is more convenient for our purposes because it enables us to focus on the parameters of interest, τ and δ. Also note that the error-correction parameterization (5) cannot be estimated directly using ordinary least squares because it is nonlinear with respect to the long-run parameters, τ. Two approaches are commonly used to estimate equation (5). The two-step procedure first estimates τ using OLS in static regressions and then estimates the dynamic parameters, α and δ, conditional on the OLS estimates of τ. The one-step procedure estimates τ, α and δ simultaneously using a nonlinear least-squares (NLS) procedure with equation (5). To be consistent with the econometric literature, estimates of (5) obtained using the two-step procedure are referred to as OLS estimates and those obtained using the one-step procedure are referred to as NLS estimates.

In preliminary regressions, we tested the hypothesis that CSBs have a permanent, instantaneous effect on M2 and M2+. This hypothesis is represented by imposing the nonlinear restrictions: $\alpha_{c1} = -\alpha_{c0}\alpha_m$ and $\tau_c = \alpha_{c1}$ on (5). These restrictions could not be rejected by the data and, hence, are imposed in all the regressions reported throughout this section. We also tested the hypothesis of an asymmetric CSB effect by adding a CSB sales-period variable to equation (5).[37] The standard CSB variable was found to be statistically significant, whereas the CSB sales-period variable was found to be statistically insignificant in this encompassing regression. This implies that changes in CSB holdings during redemption periods have a statistically significant effect on M2 and M2+, a concept that is contrary to the results obtained using the monthly growth-rate equations presented in the previous section.

Table 4 presents OLS and NLS estimates of alternative cointegration vectors for M2 and M2+ and the corresponding ADF and PP tests for cointegration. As previously mentioned, our estimate of δ in equation (5) has a non-normal limiting distribution under the unit root hypothesis so that conventional inference on δ is not a statistically valid test for cointegration. However, simulation experiments by Banerjee et al. (1986) show that a conventional t-test on δ has reasonable small-sample properties at the 0.05 level. Consequently, in Table 4 we also report the estimated value of δ from error-correction models and indicate whether it is statistically significant at the 0.05 level according to a conventional t-test.

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[37] The standard CSB variable includes changes in CSBs during sales periods and redemption periods, whereas the CSB sales-period variable includes changes in CSBs during sales periods and then holds the level of CSBs constant throughout the year.

For M2, the unit root tests provide evidence of cointegration for one specification only - the ADF test statistics are significant at the 0.05 level of significance for the cointegration vector with a linear time trend. The corresponding PP test statistics for this cointegration vector are not significant at the 0.05 level. Thus, our cointegration inference is fragile with respect to the alternative unit root test statistics. The estimates of δ from the error-correction models provide evidence of cointegration but do not identify a unique cointegration vector - all four estimates of δ from the error-correction models are statistically significant at the 0.05 level. The estimates of δ, however, are considerably higher in the error-correction models that include a linear time trend. In general, the cointegration tests are not conclusive in identifying a unique cointegration vector for M2. However, in terms of using the cointegration tests for model selection, there is a preference for long-run specifications that include a linear time trend.

It is interesting to note that in comparing the OLS and NLS estimates of the cointegration vectors, the closest estimates are for vectors that include the linear time trend. This is consistent with cointegration theory. Suppose that the true cointegration vector is represented by the long-run specification: $m - p = \tau_y y + \tau_c csb + \tau_t t$. The OLS and NLS estimates of $\{\tau_y, \tau_c, \tau_t\}$ are then "superconsistent," meaning that they converge to their limiting distributions at a faster rate than consistent estimates in regressions involving stationary variables. As a result, we find that the OLS and NLS estimates of $\{\tau_y, \tau_c, \tau_t\}$ are quite similar in finite samples. Phillips' (1986) analysis of spurious regressions shows that OLS and NLS estimates obtained from regressions with integrated variables that are not cointegrated do not have meaningful statistical interpretations. Hence, the OLS and NLS estimates of τ diverge substantially when the time trend is excluded from the cointegration vector.

For M2+, the unit root tests provide no evidence of cointegration at the 0.05 level for the specifications. The estimates of δ from the error-correction models are statistically significant for specifications without a linear time trend. On this basis, there is a preference for excluding the linear time trend from error-correction models for M2+. This preference is also supported by the ADF and PP test statistics. Engle and Yoo (1987) show that adding variables to the hypothesized cointegration vector increases the critical values for the ADF test statistic. The results in Table 4 indicate that adding the time trend and R90 to the cointegration vector has little effect on the ADF and PP test statistics. Thus, the ADF and PP test statistics as well as the estimates of δ from the error-correction models suggest that only real income and CSBs are appropriate in the long-run specifications for M2+.

The cointegration tests reported in Table 4 suggest that the velocity of M2 (but not of M2+) has a deterministic trend component. This is somewhat surprising given that the ratio of M2+ to nominal spending exhibits more of a trend than the ratio of M2 to nominal spending (see Figure 2). This can be reconciled by noting that M2+ has a higher long-run income elasticity relative to that of M2 in the regression analysis. In the velocity charts, the long-run income elasticities for both M2 and M2+ are implicitly constrained to be unity.

Note that in the static regressions, the linear time trend is positive and reduces the estimated long-run income elasticity for both M2 and M2+. This is also the case for the error-correction model of M2. However, in the error-correction model of M2+, the linear time trend is negative and increases the estimated long-run income elasticity. We are puzzled by why the one-step and two-step estimation procedures result in different signs on the linear time trend for M2+. Under the cointegration hypothesis, the OLS and NLS estimates of the parameter on the linear time trend are superconsistent and, hence, are expected to be similar in finite samples. This may be evidence of non-cointegration, in which case the OLS and NLS estimates of the parameter on the linear time trend have no meaningful statistical interpretation.

One way to interpret the ADF and PP unit root test results is that the velocity of M2 and M2+ has a unit root and, hence, the demand for M2 and M2+ should be modelled in first-difference form (as in the previous section). An alternative interpretation is that the velocity of M2 and M2+ has a "near unit" root. Under this interpretation, there is a cointegration relationship underlying the long-run demand for M2 and M2+ but the cointegration tests lack the power required to identify the cointegration vector. Given that unit root tests are known to lack power, this possibility is worthy of further consideration. Section 3.2.2 proceeds under the cointegration hypothesis and re-examines the alternative long-run specifications for M2 and M2+ using a conventional statistical analysis.

3.2.2 The conventional approach

In this section, we make inferences about the long-run M2 and M2+ demand functions using conventional distribution theory. Our analysis focusses solely on the NLS estimates of error-correction models for M2 and M2+ because these estimates encompass the corresponding OLS estimates.[38] The same error-correction specifications as in the cointegration tests reported in Table 4 are examined, but we apply the likelihood-ratio (LR) principle, rather than the cointegration tests, as a basis for model selection.

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[38] The dominance of the statistical fit of the NLS estimates over the OLS estimates is guaranteed by the maximization principle underlying the NLS iterative-estimation algorithm.

The logs of the likelihood functions are reported in Table 4 for the NLS estimates of the error-correction models. We can choose among the four alternative specifications for M2 and M2+ by performing a series of nested likelihood-ratio tests. First, with respect to the error-correction models for M2, the LR tests indicate that R90 has a marginal significance level (MSL) of 0.86, the linear time trend has an MSL of 0.08, and that R90 and the linear time trend jointly have an MSL of 0.45. Thus, using, for instance, a 0.10 significance level, we would select the long-run M2 specification with the linear time trend as in the cointegration analysis. At a higher level of significance, say the 0.05 level, we would select the long-run M2 specification that excludes the linear time trend. With respect to the long-run specifications for M2+, the LR tests indicate that R90 has an MSL of 0.09, the linear time trend has an MSL of 0.19 and that R90 and the linear time trend jointly have an MSL of 0.04. Thus, on the basis of the LR principle, we would select the long-run specification involving both R90 and the linear time trend as being most appropriate for M2+.

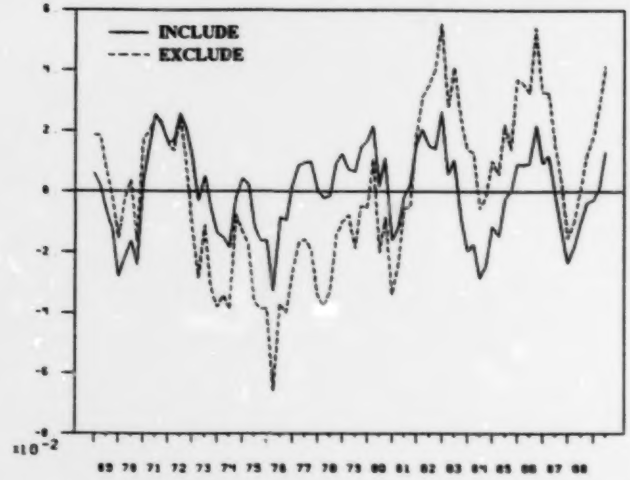
The above analysis reveals that specification searches based on cointegration tests do not necessarily correspond with searches based on conventional statistical criteria for model selection. For M2, the cointegration tests indicate that the linear time trend is an important component in the long-run demand function, whereas the LR tests indicate that the linear time trend is only marginally significant (MSL of 0.08). For M2+, the cointegration tests indicate that neither the linear time trend nor R90 are important components in the long-run demand function, whereas the LR tests indicate that the linear time trend and R90 together are statistically significant.

3.2.3 A graphical comparison of alternative cointegration vectors

The results obtained from the statistical analysis of cointegration performed previously can be illustrated graphically. In this section, we examine the deviation of actual M2 and M2+ from their long-run equilibrium implied by the alternative estimates of the cointegration vector. Intuitively, M2 and M2+ should revert to their true cointegration vector more frequently than to non-cointegrating vectors. Thus, this graphic procedure may provide some insights into the statistical analysis performed in the previous section. We next examine two identification issues: (i) Does the linear time trend improve the tendency of M2 and M2+ to return to long-run equilibrium? (ii) Given the ongoing shifts in market share between deposits held at banks and near-banks, does M2+ tend to revert to its long-run equilibrium more frequently than M2?

Figure 12 illustrates the effect of including a linear time trend in the long-run demand for M2. The broken line represents the deviation of real M2 from its long-run equilibrium implied by the NLS estimates of the cointegration vector that excludes the time trend: $m - p = 1.305y - 0.100csb$. The solid line represents the deviation of real M2 from its long-run equilibrium implied by the OLS estimate of the cointegration vector that includes the time trend: $m\text{-}p = 0.691y - 0.100csb + 0.00697t$. The two long-run specifications have the same CSB elasticities and, hence, the divergence between the two lines represents the effect of detrending real M2 with a time trend and a lower income elasticity. Figure 12 shows that incorporating a linear time trend into the equation implies that M2 was much closer to its long-run equilibrium throughout the 1973-79 period. This figure also suggests that when the time trend is excluded from the long-run specification, M2 permanently shifts above its long-run equilibrium in 1982. This is consistent with the consolidation-period hypothesis presented in the introduction to this paper. Note, however, that when the time trend is included in the long-run

Figure 12
The Effect of a Time Trend on the Long-Run Demand for M2



specification there is no indication of a permanent shift in 1982 - M2 cycles around its long-run equilibrium throughout the 1980s. Thus, the inclusion of the time trend in the long-run specification appears to preclude a 1982Q2-84Q4 consolidation-period shift in the velocity of M2.

Figure 13 shows the effect of including the linear time trend in the long-run demand for M2+ employing the same analysis as that used for M2 above. The broken line represents the deviation of real M2+ from its long-run equilibrium implied by the NLS estimates of the cointegration vector excluding the time trend: $m - p = 1.509y - 0.091csb$. The solid line represents the deviation of real M2+ from its long-run equilibrium implied by the OLS estimate of the cointegration vector that includes the time trend: $m-p = 1.157y - 0.103csb + 0.00384t$. Figure 13 shows that the time trend has less effect on the tendency of M2+ to revert to its long-run equilibrium than was the case for M2. The time trend accounts, to some extent, for M2+ being below its long-run equilibrium over the 1973-76 period, but then implies

Figure 13
The Effect of a Time Trend on the Long-Run Demand for M2+

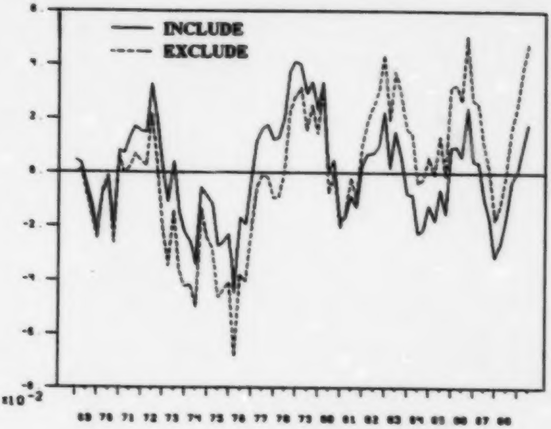
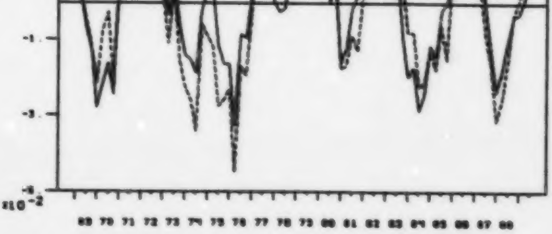


Figure 14
The Long-Run Demand for M2 and M2+



a larger divergence of M2+ above its long-run equilibrium over the 1977-79 period. As found for M2, including the time trend in the long-run specification appears to preclude the 1982Q2-84Q4 consolidation-period shift in the velocity of M2+.

Figure 14 provides some insight into the effect of market-share shifts on the velocity of M2. The solid line represents the deviation of real M2 from its long-run equilibrium implied by the OLS estimate of the cointegration vector: $m-p = 0.691y - 0.100csb + 0.00697t$. The broken line represents the deviation of real M2+ from its long-run equilibrium implied by the OLS estimate of the cointegration vector: $m-p = 1.157y - 0.103csb + 0.00384t$. The divergence between the solid and broken lines in Figure 14 is intended to represent the effect of market-share movements on the long-run demand for M2. As shown in Figure 14, throughout the sample period M2 exhibits much of the same tendency to revert to its long-run equilibrium as does M2+ - with the exception of the 1977-79 period when M2+ was further above its long-run equilibrium than M2. This graphic analysis suggests that the ongoing decline in the share of M2 deposits within M2+ has had little effect on the tendency of M2 to revert to its long-run determinants.

3.2.4 An examination of the long-run price homogeneity restriction

The analysis up to this point has assumed that long-run price homogeneity holds. This restriction was generally supported by the monthly equations with Almon lag structures presented in the previous section. We now examine whether this restriction is valid for the regressions represented in Table 4. First, we consider the implications of relaxing the long-run price homogeneity restriction on the ADF and PP tests for cointegration. Then we apply conventional statistical procedures to test the statistical validity of the long-run price homogeneity restriction in the context of the error-correction models referred to in Table 4.

To determine the implications of the long-run price homogeneity restriction on the cointegration tests, we re-estimate the static regressions in Table 4 using nominal M2 and M2+ as dependent variables and then perform unit root tests on the residuals. The OLS estimates of the unrestricted long-run price parameters in the static regressions are generally found to be greater than unity. The ADF and PP test statistics obtained from the residuals of static regressions with the unrestricted price elasticity are unchanged from those obtained from residuals of static regressions with long-run price homogeneity imposed. Thus, the long-run homogeneity restriction cannot account for our inability to reject the non-cointegration hypothesis.

As previously mentioned, statistical procedures based on standard normal asymptotic distribution theory are invalid for testing restrictions on variables that are I(1). However, West (1988) shows that for variables that are I(1) with drift, the parameter estimates have normal limiting distributions and, hence, conventional inference procedures are valid. This result is relevant for testing long-run price homogeneity restriction in our analysis. Since our univariate unit root analysis indicated that the price level is I(1) with drift, conventional inference can be used to determine the statistical validity of the long-run price homogeneity restriction. Unrestricted estimates of the long-run price elasticity in the error-correction models for M2 and M2+ are found to be considerably below unity. LR tests are able to reject the long-run price homogeneity restriction in all of the error-correction models. Thus, conventional inference procedures indicate that our models are inconsistent with long-run price homogeneity.

Given the strong rejection of long-run price homogeneity in the error-correction models but not in the monthly growth-rate models presented in Section 2, we attempted to determine whether the rejection is due to the unit root hypothesis. This possibility was examined by testing the long-run price homogeneity restriction in the context of quarterly growth-rate models for M2 and M2+.

Growth-rate specifications for M2 and M2+ can be thought of as being nested in the autoregressive distributed-lag specification (4). If the error term, u, in equation (5) has a unit root, we can express (4) in growth-rate form as follows:

$$\begin{aligned}\alpha_m(L)\Delta m = \alpha_t &+ \alpha_p(L)\Delta p + \alpha_y(L)\Delta y + \tau_c(L)\Delta csb \\ &+ \alpha_r(L)\Delta R90 + \alpha_{rd}(L)\Delta(R90\text{-}B90) + v \qquad (6)\end{aligned}$$

where $u = u_{-1} + v$ and v is a random (stationary) error term. It is important to note that in differencing the level specification (4) the deterministic time-trend component $\tau_t t$ becomes the constant term τ_t in the growth-rate specification (6). Thus, equation (6), implies that the velocity of M2 and M2+ follows a random walk with drift where the drift component is captured by the constant term in the regression. Also note that in the above growth-rate specification, all the variables are stationary and, as a consequence, conventional statistical procedures apply.

In the context of growth-rate specifications of the form given by equation (6), the estimated unrestricted long-run price elasticity is 0.864 for M2 and 0.700 for M2+. These estimates are similar to those obtained from the monthly equations with Almon lag structures. The long-run price homogeneity restriction cannot be rejected in either equation - the LR test has a marginal significance level of 0.28 for the M2 equation and 0.07 for the M2+ equation. Thus, we find statistical evidence supporting the long-run price homogeneity restriction under the unit root hypothesis but not under the cointegration hypothesis.

Given the strong theoretical appeal of long-run price homogeneity for money demand, we prefer to interpret the tests for long-run homogeneity as a diagnostic device. From this point of view, the tests for long-run price homogeneity detect evidence of misspecification in the error-correction models for M2 and M2+ but not in the growth-rate models. At the present time, the source and implications of this misspecification are less than clear and remain an important area of future research.

Once again, we find the differences between the one-step and two-step estimates of the long-run parameters to be rather puzzling. Under the cointegration hypothesis, the OLS and NLS estimates of the long-run price elasticity are superconsistent. Consequently, it is unlikely that the divergence in the estimates is due to a difference in the small-sample properties of the OLS and NLS estimators. One explanation is that the divergence in OLS and NLS estimates is an indication that the cointegration hypothesis does not hold. Another possibility is that the NLS estimates of the cointegration vector are sensitive to the specification of the short-run dynamics. It is possible that the bias resulting from misspecified dynamics in the NLS procedure outweighs the efficiency gains from using NLS. These explanations are, however, merely speculative.

3.2.5 Are there discrete breaks in the velocity trend function?

Our analysis of the long-run demand for M2 and M2+ has so far considered two alternative specifications of the velocity function. The error-correction models are specified under the maintained hypothesis that the velocity functions for M2 and M2+ are either mean-stationary or trend-stationary: the error-correction specification without the linear time trend implies that velocity is a mean-reverting process; the error-correction specification with the linear time trend implies that velocity is a trend-reverting process. In contrast, the growth-rate equations imply that the velocity function is nonstationary - velocity follows a random walk process with drift. These different stochastic processes for velocity may not adequately capture velocity shifts that may have occurred throughout the sample period. For example, beginning in the early 1980s, the personal sector has been able to acquire relatively small denominations of treasury bills from investment dealers with lower transactions costs. This institutional development has increased the substitutability between treasury bills and personal savings deposits and, to some extent, may have shifted the velocity of M2 and M2+. Velocity shifts of this nature may be characterized as permanent discrete shifts in the trend function.

Perron (1989) has shown that unit root tests are biased towards non-rejection when discrete shifts in the trend function are unaccounted for. This may explain our difficulty in finding support for the cointegration hypothesis. However, it is not clear how such shifts can be identified. On a purely *a priori* basis, there is no single innovation that seems to have been of major importance. Instead, a number of developments have occurred that are possibly of some significance in accounting for permanent shifts in the velocity of M2 and M2+. However, the exact timing of these developments and their effects on the velocity of M2 and M2+ are quite uncertain.

In this section, we examine the cointegration implications of a permanent discrete shift in the velocity function of M2 and M2+ that has been hypothesized in previous research. This shift has been referred to as the "consolidation period" in the monthly growth-rate equations presented in the second section of this paper. Estimates (in Section 3.2.4) of the M2 and M2+ monthly equations with a dummy variable to capture possible velocity shifts over the 1982Q3-84Q4 period, indicate that M2 permanently declined by 6.7 per cent and M2+ by 7.9 per cent. We next examine the implications on the long-run money-demand function of including a consolidation-period shift variable in the cointegration analysis and in the error-correction models.

The consolidation-period shift variable finds no support in static regressions of the type reported in Table 4 - OLS estimates of the consolidation-period shift variable (not shown) are either positive or empirically very small. We do find evidence in support of the consolidation-period hypothesis in the context of the error-correction models - the consolidation-period shift variable is estimated to be statistically significant and accounts for a permanent decline of 8.8 per cent in M2 and 6.6 per cent in M2+. These estimates are roughly consistent with those implied by the monthly growth-rate equations. Thus, our inference with regard to the consolidation-shift hypothesis is conditional on the methodology used - we find significant statistical evidence using conventional inference procedures but no evidence with the cointegration approach.

We should emphasize that the constructed consolidation-shift variable was originally specified on the basis of the dynamic simulation performance of the monthly growth-rate equations. Thus, given the high degree of pre-test bias involved in this identification procedure, inferences based on this constructed shift variable are quite difficult to interpret. Moreover, casual observation of Figures 12 and 13, showing the deviation of real M2 and M2+ from their long-run determinants, suggests little evidence of such a shift once a time trend is included in the M2 and M2+ specifications. Thus, although the consolidation-shift variable is found to improve the statistical fit of the error-correction models, it is not clear whether our understanding of velocity movements is improved when we resort to identification procedures of this nature.

To summarize briefly, cointegration tests provide little evidence to support the existence of cointegration between M2 and M2+ and the explanatory variables included in the long-run demand function. Thus, we are unable to reject the hypothesis that the velocity functions for M2 and M2+ have a unit root. We find a substantial difference between the long-run demand functions for M2 and M2+ identified by using cointegration tests as the basis for model selection. For M2, cointegration tests indicate that the level of interest rates (R90) has little effect on the long-run demand for M2, but that a linear time trend is important in accounting for trend movements in M2. For M2+, cointegration tests indicate that neither the level of interest rates (R90) nor a linear time trend has an important impact on the long-run demand for M2+.

It should be emphasized that our inability to make credible inferences about the long-run demand for M2 and M2+ is, to a large extent, due to the limited degrees of freedom available and to the low power of the statistical techniques used. Increasing the degrees of freedom for these tests by examining a longer historical series for M2 and M2+ may provide some important insights into these issues.[39] There may also be some gain in applying more powerful cointegration tests that are currently being developed. Moreover, it would be particularly useful to examine these hypotheses using statistical procedures developed by Phillips (1989) and Johansen (1988) which enable us to make valid inference on cointegration vectors. This remains an area for future research. In the meantime, it is interesting to consider the implications of our uncertainty about the appropriate long-run specification for M2 and M2+ in terms of the short-run dynamic properties.

3.2.6 An examination of the short-run dynamic properties of M2 and M2+ implied by the different long-run demand functions

The cointegration analysis of the long-run demand for M2 and M2+ in the previous section was unable to determine conclusively whether the velocity of M2 and M2+ is mean-stationary, trend-stationary or nonstationary.

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[39] Strictly speaking, M2 and M2+ cannot be constructed, as defined, prior to 1968 because non-personal notice deposits are not available. However, since non-personal notice deposits make up a relatively small proportion of M2 and M2+ in 1968, this data problem is probably not severe. Previous research, however, has shown evidence of instability in the demand for M2 in the 1960s (see Clinton, 1973). Given the possibility of structural instability, it is not clear if we will be better able to find evidence of cointegration using longer historical series for M2 and M2+.

These three stochastic processes for the velocity function can be summarized by three alternative money-demand specifications: an error-correction model with a linear time trend implying that the velocity function is stationary around its deterministic trend component; an error-correction model without a linear time trend, implying that the velocity function is stationary around its mean; and a growth-rate model with a constant term that implies that the velocity function follows a random walk with drift. In this section, we examine the dynamic implications of modelling velocity using these three alternative money-demand specifications.

Estimates of the three alternative specifications were obtained using dynamic specifications given by equation (5) for the error-correction models and by equation (6) for the growth-rate model. R90 was found to be statistically insignificant in all three specifications and was excluded from the analysis. The resulting estimates are reported in Table 5 for M2 and in Table 6 for M2+. We also present estimates of simple partial-adjustment models for M2 and M2+ to serve as a reference point. The partial-adjustment specification is given by[40]:

$$\begin{aligned}\Delta m = \alpha_0 + \alpha_y y + \tau_c[csb - (1-\delta)csb_{-1}] \\ + \alpha_{rd0}(R90 - B90) - \delta(m_{-1} - p). \qquad (7)\end{aligned}$$

Note that for the M2 specifications reported in Table 5, the error-correction model with the linear time trend has the lowest standard error. For the M2+ specifications reported in Table 6, the error-correction model

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[40] Note that equation (7) is, strictly speaking, not a simple partial-adjustment model because CSBs are constrained to have an instantaneous permanent effect on M2 and M2+. This constraint is imposed to make the CSB effect the same in all models.

Table 5
Alternative Dynamic Specifications for M2
Sample: 1969Q1-1989Q3

	Error-correction models		**Growth-rate model**	**Partial-adjustment model**
α_0	0.516	-0.359	-	-1.100
	(0.564)	(0.144)		(0.171)
α_m	0.148	0.217	0.353	-
	(0.109)	(0.102)	(0.101)	
α_{p0}	0.221	0.129	0.215	0.171
	(0.129)	(0.117)	(0.119)	(0.025)
α_{p1}	0.476	0.363	0.431	-
	(0.131)	(0.114)	(0.115)	
α_{y0}	0.170	0.174	0.185	0.261
	(0.067)	(0.067)	(0.067)	(0.036)
α_{y1}	0.114	0.106	0.085	-
	(0.071)	(0.071)	(0.071)	
α_{rd0}	-0.200	-0.159	-0.228	-0.390
	(0.160)	(0.160)	(0.149)	(0.140)
α_{rd1}	-0.675	-0.644	-0.797	-
	(0.178)	(0.179)	(0.144)	
α_{rd2}	0.464	0.591	-0.162	-
	(0.168)	(0.152)	(0.163)	
τ_c	-0.104	-0.100	-0.101	-0.114
	(0.017)	(0.018)	(0.017)	(0.018)
δ	0.179	0.094	-	0.171
	(0.063)	(0.034)		(0.025)
Estimated long-run income elasticity (τ_y) and linear trend component (τ_t)				
τ_y	0.752	1.305	0.418	1.519
τ_t	0.00533	-	0.00593	-
$\bar{R}^2$	0.775	0.767	0.735	0.589
S.E.E. (%)	0.572	0.579	0.604	0.733
D.W.	2.01	2.04	2.10	1.26

Notes to Tables 5 and 6:

1. Standard error given in parentheses
2. The error-correction models correspond to equation (4), the growth-rate model to (5) and the partial-adjustment model to (6).

Table 6
Alternative Dynamic Specifications for M2+
Sample: 1969Q1-1989Q3

	Error-correction models		**Growth-rate model**	**Partial-adjustment model**
α_0	-0.137 (0.067)	-0.603 (0.209)	-	-1.578 (0.182)
α_m	0.331 (0.113)	0.245 (0.121)	0.628 (0.095)	-
α_{p0}	0.148 (0.100)	0.130 (0.097)	0.121 (0.103)	0.175 (0.018)
α_{p1}	0.331 (0.098)	0.282 (0.093)	0.250 (0.100)	-
α_{y0}	0.171 (0.056)	0.164 (0.056)	0.159 (0.059)	0.309 (0.033)
α_{y1}	0.143 (0.063)	0.150 (0.063)	0.081 (0.062)	-
α_{rd0}	-0.313 (0.123)	-0.228 (0.127)	-0.186 (0.127)	-0.526 (0.099)
α_{rd1}	-0.350 (0.153)	-0.379 (0.147)	-0.456 (0.120)	-
α_{rd2}	0.293 (0.130)	0.256 (0.124)	0.022 (0.127)	-
τ_c	-0.103	-0.092 (0.015)	-0.082 (0.015)	-0.124 (0.012)
δ	0.083 (0.038)	0.099 (0.032)	-	0.175 (0.018)
Estimated long-run income elasticity (τ_y) and linear trend component (τ_t)				
τ_y	1.156	1.512	0.645	1.770
τ_t	0.00384	-	0.00335	-
$\bar{R}^2$	0.785	0.804	0.756	0.722
S.E.E. (%)	0.515	0.471	0.515	0.535
D.W.	1.98	1.92	2.27	1.55

without the time trend has the lowest standard error.[41] This offers some support for the cointegration analysis performed in Section 3.2.1. Moreover, with reference to statistical fit, the error-correction models are generally preferred over the growth-rate models for both M2 and M2+. Thus, although we were unable to find conclusive statistical evidence of cointegration, there is little evidence of any efficiency gains from imposing the unit root restriction on the data.

To analyze the differences in dynamics implied by the four alternative specifications, we focus on the relationship between movements in nominal spending and M2. To do this, we examine separately the dynamic implications of shocks to the price and real income components of nominal spending.

Consider first the effect of a one per cent permanent increase in the price level on the level of M2. The results of this simulation are reported in Table 7 for each of the four M2 specifications reported in Table 5. Since long-run price homogeneity is imposed in all four specifications, the reported effect on the level of M2 also represents the proportion of total adjustment completed. The response of the error-correction model with a time trend and the growth-rate model are quite similar - over 70 per cent of the adjustment completed after the second quarter and 90 per cent after the third quarter. This is consistent with the dynamics implied by the monthly growth-rate equations with Almon lags examined in Section 2. Excluding the time trend from the error-correction model results in a slower speed of adjustment - less than 70 per cent of the total adjustment is completed after three quarters. If simple partial-adjustment dynamics are used, an even slower dynamic response results - less than 50 per cent of the adjustment is completed after three quarters.

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[41] In Table 6, the error-correction model for M2+ with a time trend is estimated using a two-step procedure instead of the one-step procedure. This avoids the negative time trend and large long-run income elasticity implied by the one-step procedure. In addition, the OLS estimates of the long-run specification for M2+ are preferred over the NLS estimates by the cointegration tests.

Consider next the dynamic response of the four models with respect to a one per cent permanent shock to real income. This is also shown in the simulation results reported in Table 7. The response of M2 implied by the error-correction and growth-rate models is quite similar in the first few quarters after the income shock - in the 0.170 to 0.185 range in the first quarter, and in the 0.309 to 0.317 range in the second quarter. However, these models have quite different long-run income elasticities and, hence, the implied rates of adjustment are much different. The growth-rate model has the lowest long-run income elasticity (0.417) and has the most rapid adjustment - over 90 per cent of the adjustment is complete in the third quarter. The error-correction model with the time trend has the second lowest long-run elasticity (0.752) and the second highest rate of adjustment - just under 60 per cent of total adjustment is completed in the third quarter. If the time trend is excluded from the error-correction model, the result is a much higher long-run income elasticity (1.302) and an even slower adjustment rate.

The price shock simulations reported in Table 7 indicate that the unit root hypothesis alone does not result in faster adjustment speeds - the error-correction model with the time trend implied a faster response of M2 to price shocks than the growth-rate model. Consequently, a preference for growth-rate specifications for M2 on the basis of more plausible implied adjustment behaviour is unjustified. The estimated long-run elasticities (particularly for real income) and adjustment rates are substantially affected by the inclusion of the linear time trend in the model (drift in the growth-rate specification). Including a linear time trend in the long-run demand function for M2 (as

Table 7
Simulations of Alternative Dynamic Specifications for M2

Effect of 1% permanent increase in the price level on the level of M2

	Error-correction models:		Growth-rate	Partial-adjustment
Quarters	w trend	w/o trend	model	model
1	0.221	0.129	0.215	0.172
2	0.729	0.520	0.722	0.314
3	0.944	0.687	0.900	0.432
4	1.024	0.768	0.964	0.530
5	1.046	0.815	0.986	0.611
6	1.045	0.847	0.994	0.677
7	1.036	0.871	0.996	0.733
8	1.027	0.891	0.998	0.779
∞	1.000	1.000	1.000	1.000

Effect of 1% permanent increase in the level of real income on the level of M2

	Error-correction models:		Growth-rate	Partial-adjustment
Quarters	w trend	w/o trend	model	model
1	0.170	0.174	0.185	0.261
2	0.309	0.317	0.335	0.477
3	0.434	0.455	0.388	0.656
4	0.531	0.578	0.407	0.804
5	0.603	0.684	0.413	0.926
6	0.653	0.775	0.416	1.028
7	0.687	0.854	0.417	1.112
8	0.710	0.921	0.417	1.182
∞	0.752	1.302	0.417	1.516

Proportion of total adjustment completed in response to real income shock

	Error-correction models:		Growth-rate	Partial-adjustment
Quarters	w trend	w/o trend	model	model
1	0.226	0.133	0.443	0.172
2	0.411	0.243	0.803	0.314
3	0.577	0.350	0.931	0.432
4	0.707	0.444	0.975	0.530
5	0.802	0.525	0.991	0.611
6	0.868	0.595	0.997	0.678
7	0.914	0.655	0.998	0.733
8	0.944	0.707	0.999	0.779

indicated by the cointegration analysis) considerably increases the adjustment rates of the error-correction model. This is an indication that improving the long-run specification for the demand for money is critical to improving our understanding of the underlying dynamics.

It should be emphasized that the general concept of adjustment speeds requires clarification. The simulations reported in Table 7 show that the error-correction models imply much more rapid adjustment to price shocks than to income shocks. Consequently, the dynamic adjustment of the error-correction models is not summarized satisfactorily by the parameter δ. This is more obvious when we compare the dynamics of the error-correction model including the time trend with those of the partial-adjustment model. Both models have estimates of δ close to 0.17, but have much different rates of adjustment with respect to price and income shocks.

We should also question whether rapid adjustment with respect to income shocks is preferred on theoretical grounds since there is considerable uncertainty surrounding the relationship between the estimated lag structures on income and the adjustment lags that are thought to occur at the individual level. This is especially relevant with regard to the relationship between income shocks and the ensuing movements in broad monetary aggregates examined in this paper. If income is serving as a proxy for permanent income or some other concept of wealth, it is not clear on theoretical grounds that we should have a strong preference for models with short rather than long adjustment lags on income. What is required instead, is to extend the analysis first to explore the links between income and permanent income (or wealth) and then to consider the implications of using the derived measure of permanent income (or wealth) in the demand-for-money function. Analysis along these lines represents a more credible basis for model selection.

4. Demand for the Components of M2

4.1 Introduction

For the models in Sections 2 and 3 to capture correctly the aggregate demand for money in the Canadian economy, certain aggregation conditions must be met. Two methods for disaggregating monetary aggregates readily present themselves: a classification by type of deposit (as in previous studies of the demand for money that use Divisia indices, for example), and a classification by type of ownership. In this section, we consider the latter approach and ask whether an examination of M2 disaggregated into three components - namely, currency, personal-sector deposits (personal M2) and non-personal deposits (non-personal M2) - can enhance our understanding of some of the issues regarding the demand for broad money discussed in Sections 2 and 3. Since this classification is not possible for the "plus" component of M2+, we focus on M2.

We begin with the general theoretical specification used in the previous two sections - namely, that the long-run demand for each component is a function of scale, price and interest rate variables. We consider whether the responses of the components of M2 to variations in these variables differ to any important extent and, if so, whether variations in the shares of ownership are important in explaining movements in aggregate M2 over the sample period.

In addition, we investigate whether any economic variables, such as wealth, proxies for the cost of financial intermediation and the earnings-price ratio (a measure that could be related to the rate of return on equity, or which could capture the wealth effects of changing equity values) can reasonably explain the downward shift in demand for the broad aggregates in the 1982-84 period that was identified in earlier sections of this paper. We assess whether the shift is confined to any one component or whether it is evident for all three components of M2.

A number of approaches are used to model the adjustment process and to assess the significance of the relationships. First, to model the dynamics, we adopt the single-equation autoregressive distributed-lag (ADL) approach (equivalent to the single-equation error-correction model used in Section 3) rather than the Almon lag specification employed in Section 2.

We begin with the conventional classical approach to estimation, presume that there is a cointegration relationship between the variables involved, and make use of asymptotic normal distribution theory to make inferences about the estimates provided by the ADL regressions specified in *levels* form. As described in the previous section, for the parameters of long-run money demand to be estimated consistently, and for inferences about the true values of these parameters to be valid, strong assumptions regarding the properties of the regressors and error term are required. We then formally test the cointegration hypothesis and, as in the previous section, consider whether a cointegrating relationship can be detected in the data either among the basic variable set which includes money, prices, income, and interest rates, or by using an augmented variable set (which adds the earnings-price ratio, cost of financial intermediation, etc.). We also consider estimates of money demand derived from first-difference dynamic regressions for which, in the absence of cointegration, the requirements for consistency and, possibly, for correct inference are more likely to be met. Given the low power of the tests for cointegration, we are interested in assessing how robust the estimates of the long-run demand of the components of M2 are to different methods of estimation - namely error-correction models on "levels," static cointegrating regressions and first-difference dynamic specifications.

For each equation, we start with real gross domestic product (GDP) as the scale variable, its price deflator (PGDP) as the price variable, and the 90-day commercial paper rate (R90) as the interest rate variable. Alternative measures of scale, price and interest rates are also tested and retained if they significantly improve the estimation results and simulation properties. In addition, other variables that are specific to the component being estimated are also tested. Quarterly data are used.

Finally, we assess how forecasts of aggregate M2 based on the approach used in Section 2 compare with those made from the disaggregated model developed in this section.

For each component, a general distributed-lag loglinear equation, (which includes a constant and a linear time trend in addition to the price, scale and interest rate variables), is taken as the general starting point for the model. The order of the equation is decided on the basis of Akaike's Final Prediction Error (FPE).[42] From this basic equation, t-tests and the standard error of the regression are used as criteria to eliminate insignificant regressors and achieve a more parsimonious specification. If new variables are added to an equation, the specification process begins again by selecting the optimal lag length.[43] With a view to clarifying the nature of the 1982-84 shift detected in the aggregate monthly equations and, more generally, in order to investigate the stability of the demand equations, rolling Chow tests are used to detect any breaks in structure within the sample period. Finally, the *ex post* dynamic simulation properties of the chosen equations are considered. Given the likelihood of pre-test bias, the possible endogeneity of some of the regressors and the nonstationary nature of most of the regressors (as demonstrated in the previous section), an examination of the simulation properties is important in evaluating the performance of the chosen equations.

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[42] Although other criteria are available, the FPE seems a reasonable criterion to use since, in finite samples, the Schwarz Bayesian Information Criterion tends to underfit the model, the $\bar{R}^2$ tends to overfit, while the Akaike Information Criterion gives results similar to the FPE.

[43] Note that this approach to model selection is somewhat different from that used in Section 3.

Before presenting our results, we emphasize two differences between the approach in this section and that used in Section 3. First, for the personal and non-personal M2 equations, a shorter sample period is used. The sample begins in 1975 instead of 1969 as in Section 3 because data on personal and non-personal M2 are available separately only from 1974 onward. The sample ends in 1987 rather than in 1989 so that post-sample observations can be used to assess the model and compare it to aggregate M2 equations similar to those in Section 2. Second, since one of the aims of this section is to extend the analysis of the potential determinants of money demand, as well as to consider various hypotheses for the source of the downward shift in aggregate M2 in the 1982-84 period, a wider set of potential explanatory variables is considered in this section. These additional variables include wealth, financial intermediation spreads and the earnings-price ratio.

4.2 A look at the disaggregated M2 data

We begin with some descriptive statistics. It should be noted that the commonly used measures of the monetary aggregates are net measures (i.e., net of private-sector payments in transit (float). However, since data on float are not available for personal-sector deposits and non-personal deposits separately, the measures for M2, personal M2 and non-personal M2 used in this section are gross measures.

Figure 15, which shows the level of each component and of total M2, relative to nominal income (gross domestic product), is useful in illustrating movements in the relative shares of the components. The share of M2 accounted for by currency, which is held by both the personal and non-personal sectors,[44] declined steadily from about 12.5 per cent in 1968 to less than 8.5 per cent in 1988. The share of non-personal deposits, most of which

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[44] Information on the ownership of currency balances (personal versus non-personal sectors) is not available.

Figure 15
Components Relative to Nominal GDP

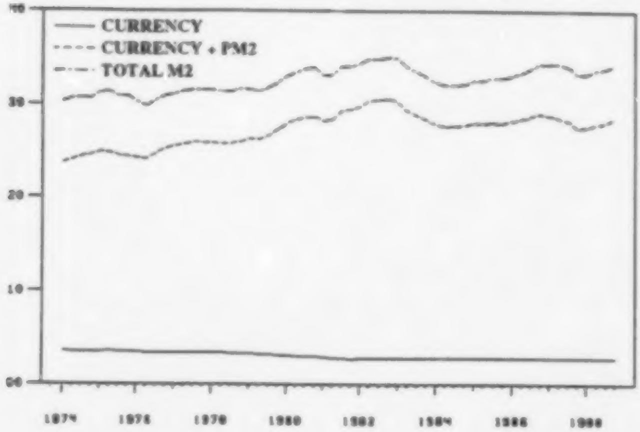


Figure 16
Currency - Quarterly Growth Rate

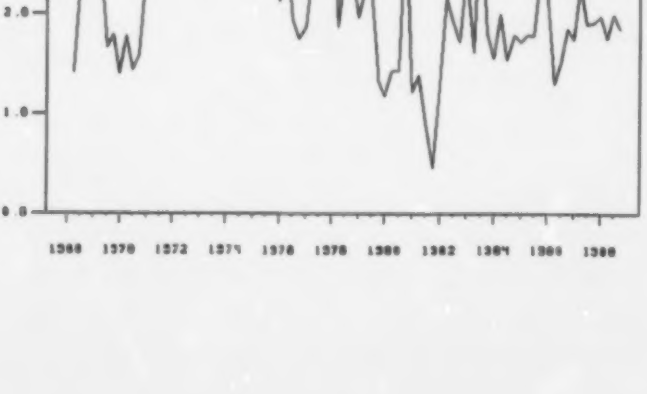


Figure 17
Personal M2 - Quarterly Growth Rate

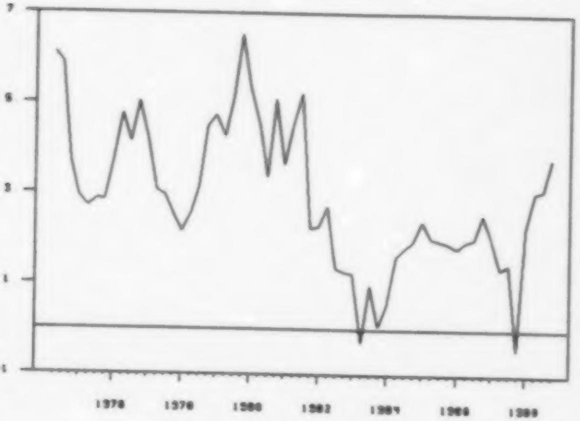


Figure 18
Non-Personal M2 - Quarterly Growth Rate

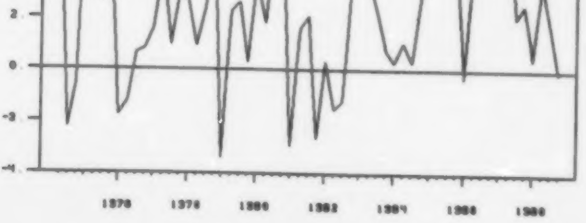


Figure 19
Total M2 - Quarterly Growth Rate

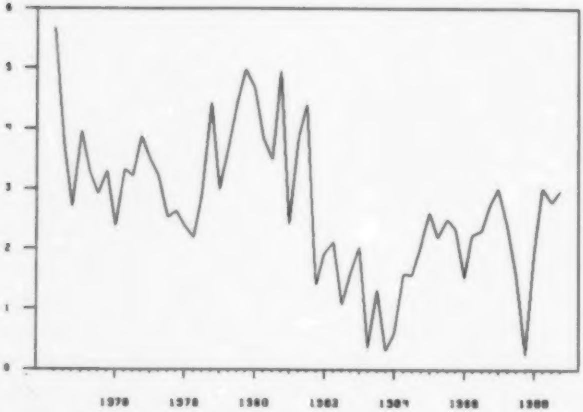
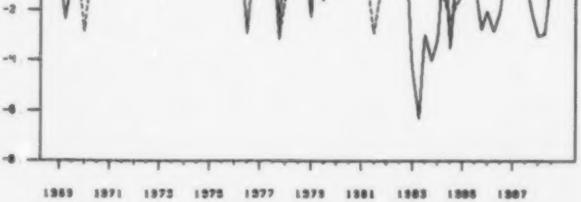


Figure 20
Disposable Income and Consumption (vs GDP) - Quarterly Growth Rates



are transactions-type balances,[45] fell from almost 22 per cent in early 1974 to about 12.5 per cent in mid-1982, but then recovered to about 17.5 per cent in late 1988. Personal M2 deposits accounted for about two-thirds of M2 in early 1974; the share peaked at more than 79 per cent in 1982 and then fell back to 74 per cent by the end of 1987. In contrast to non-personal M2, much of personal M2 consists of savings-type balances, of which non-chequable savings accounts and fixed-term deposits account for substantial proportions.

Table 8 shows the average quarterly rates of growth of total M2 and its components and their standard deviations (over the 1974-88 period). Personal M2, with growth that averaged more than 12 per cent per year (compound annual rates), is the fastest-growing component. Currency is the slowest at just over 8.5 per cent per year, but also exhibits the most stable growth over the sample period. The standard deviation of personal M2 growth is twice that of currency growth and that of non-personal M2 is four times that of currency growth.[46]

Table 8
Components of M2: Descriptive Statistics
(1974Q2-1988Q4)

	Quarterly growth rate:	
	Mean	**Standard deviation**
Total M2	2.7	1.2
Currency	2.1	0.7
Personal M2	2.9	1.6
Non-personal M2	2.3	2.7

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[45] Almost all non-personal deposits are chequable - either as current account balances or as chequable notice accounts. Savings-type balances such as fixed-term deposits held by the non-personal sector are excluded from M2 and appear in M3.

[46] Note that at monthly frequencies, currency is relatively more volatile.

The differing trends in the growth rates of the components are evident in Figures 16 to 19 which show the quarterly rates of growth of the components and of total M2. An econometric analysis of disaggregated M2 must attempt to account for this differing behaviour of the components.

4.3 The currency equation

The FPE criterion selected a third-order distributed-lag model (including a constant term and a linear time trend) as the starting point for the currency equation. The equations were estimated in loglinear form over the 1969Q1-1987Q4 period.

Initial regressions showed that the scale variable, real GDP, entered with insignificant and sometimes negative coefficients. Real consumer spending also produced a negative effect but real personal disposable income, defined as nominal disposable income deflated by the consumer expenditure deflator, yielded results more consistent with theoretical priors and was therefore used. Figure 20 illustrates the differences in these measures of scale over the sample period. To be consistent with the choice of scale variable, the GDP-based price variable was replaced by the consumer expenditure deflator. Deletion of insignificant variables (which included the time trend) and use of the standard error of the regression as a selection criterion produced equation (C1) in Table 9. The long-run price elasticity is 0.6, considerably below one. Real disposable income has the expected positive sign (with a long-run elasticity of 1.2) and the elasticity with respect to R90, the 90-day commercial paper rate, is -0.31.

Although a rolling Chow test does not detect any break over the 1982-84 period, it does give some indication of structural instability in the late 1970s, with F-values of about 4 in the 1976-80 period (compared to a critical value of just over 2). When split into pre- and post-1980 subperiods, the long-

Table 9
Currency Equations

	(C1)	(C2)	(C3)	(C4)*
		Long-run elasticities		
Price	0.6	0.6	1.0^c	1.0^c
Income	1.2	1.2	0.5	0.7
R90	-0.3062	-0.0691	-0.0579	-0.2780
		Dynamics		
Constant	-0.4 (2.1)	-5.6 (10.7)	3.0 (8.0)	
m				
1	1.10 (19.9)			0.45 (4.9)
2				-0.46 (4.7)
3	-0.17 (3.3)			
Price				
0	0.25 (3.6)	0.57 (23.1)	1.0^c	0.33 (3.0)
2	-0.21 (3.1)			-0.23 (2.2)
Income				
0	0.09 (3.3)	1.2 (28.5)	0.51 (15.3)	0.07 (2.1)
R90				
0	-0.0080 (1.9)	-0.0691 (6.5)	-0.0579 (2.4)	
1	0.0140 (3.1)			-0.026 (5.9)
$\bar{R}^2$	0.999	0.998	0.988	0.651
S.E.E.	0.00410	0.02457	0.05592	0.00463
D.W.	2.1	0.6	0.05	2.3

t-statistics in brackets
* = first-difference equation
c = constrained

Note: All regressions are estimated over the 1969Q1-1987Q4 sample period. The estimates of the dynamics are the coefficients from the regressions:
$A(L)m = \text{constant} + B(L)\text{price} + C(L)\text{income} + D(L)R90$ where all the lag polynomials are of order 3 and $A(0)=1$. The long-run effects (or estimate of the cointegrating vector, except that the constant is not reported) are given by:
$m = A(1)^{-1}\{\text{constant} + B(1)\text{price} + C(1)\text{income} + D(1)R90\}$.

run price coefficient is still different from one in each subperiod, although the constraint is most strongly rejected in the first subperiod.

Equation (C1) includes coefficients on the lagged dependent variables that sum approximately to one. Equation (C2) (which does not impose long-run price homogeneity) and equation (C3) (which constrains the long-run price elasticity to one) estimate the cointegrating vector from a static OLS regression. Augmented Dickey-Fuller tests on the residuals of these equations could not reject the null hypothesis of no cointegration.

The failure to find cointegration is not unexpected given the low power of the test. Nevertheless, given the possible nonstationarity of the error terms in (C2) and (C3), the currency equation was also estimated in first-difference form.[47] The long-run price elasticity was not found to differ from one, and so equation (C4) imposes this constraint. In addition, the constant term was found to be insignificantly different from zero and was also excluded. The long-run output and interest rate elasticities are 0.7 and -0.28, respectively. The degree of persistence as represented by the sum of the coefficients on the lagged dependent variables in this regression, is somewhat surprising. This equation passes the rolling Chow test.[48]

In summary, currency holdings are well explained by real disposable income as a scale variable, the consumption deflator, R90 and, especially, by their own lagged values. All $\bar{R}^2$s are above 0.999 in the equations specified in levels. Even when first-differenced, currency balances show very high persistence and currency growth is quite predictable (with an $\bar{R}^2$ of about two-thirds in the growth-rate equation). Though there is some evidence of instability in the "levels" equation (however, not during the consolidation period), the Chow test does not detect instability in the first-difference equation. The equation in first differences also has the appealing feature that long-run price homogeneity is not rejected. If the equations are to be used for simulation purposes, it seems preferable to impose the strong theoretical prior of a long-run unit price elasticity. On that basis, equation (C4) is chosen as the currency equation for the disaggregated M2 model.

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[47] The first-difference specification excludes the time trend.

[48] This first-differenced equation was also estimated using real GDP as a scale variable to see if using first-differenced data would improve the estimation results. However, real GDP was insignificant in the first-differenced regressions as well.

4.4 The personal M2 equation

Data for the split between personal and non-personal deposits are available for all the components of M2 deposits beginning only in 1974. To allow for lags, all regressions thus begin in 1975Q1.

Largely based on earlier modelling efforts for the aggregates M2 and M2+,[49] a number of variables in addition to a scale, price and the interest rate variable, R90, were examined in the study of personal M2. For this component, initial regressions suggested that real GDP and its deflator provided reasonable (i.e., positive) elasticities for the effects of these measures. In addition to the 90-day commercial paper rate, the 90-day term deposit rate at banks (B90) and the 90-day term deposit rate at TMLs (T90) were included. The stock of outstanding Canada Savings Bonds deflated by PGDP (csb) was also included and the role of wealth as an additional or alternative scale variable was also investigated. Several proxies for the cost of financial intermediation were tested and, finally, the behaviour of personal M2 over the 1982-84 period, identified by our research on aggregate M2 and M2+ as being of interest, was also examined.

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[49] See McPhail and Caramazza (1990).

The FPE criterion indicated that a third-order loglinear equation was an appropriate starting point. A regression of personal M2 on real GDP (y), its deflator (p), R90, B90, and csb as well as a constant and linear time trend yielded equation (P1) in Table 10. In the initial regression, the time trend was not significant and was dropped. Also, T90, the rate at TMLs, was insignificant and was deleted. The own rate, B90, has the anticipated positive effect but the coefficient on R90 is positive, contrary to our priors and, together with B90, implies a net interest rate elasticity of 0.38. The long-run price elasticity is 0.7 but the price coefficient in this equation is estimated very imprecisely. The effect of CSBs is negative on impact, but is subsequently more than reversed, leaving a net positive effect.

To allow for the possibility of substitution between personal M2 and equity, the earnings-price (EP) ratio on the Toronto Stock Exchange was included in equation (P2). Inclusion of this variable results in a large decline in the standard error of the equation. In addition, both the R90 and T90 effects are now significantly negative. The net long-run interest rate elasticity is reduced considerably to 0.10. A positive sign is not surprising given the incentive that a rise in B90 provides to switch from currency to deposits. The long-run price elasticity is 1.2, significantly different from one at the 4.5 per cent level, and the output elasticity is 2.0. CSBs now have a long-run effect that is negative (-0.12) and not too different from the impact effect. The high value of the Durbin-Watson statistic suggests that autocorrelation may be a problem in this equation.

The behaviour of personal M2 between 1982 and 1984 was then examined more closely, owing to our finding that the aggregate M2 equation suggested a downward shift in money demand during this period. For personal M2, it is difficult, with the method used in this section (the rolling Chow test), to find evidence of such a shift. Equation (P2) shows no evidence of instability as it easily passes a rolling Chow test over the whole period.

Equation (P1), however, does not pass such a test: F-values rise to about 5 within the 1982-84 period, indicating a structural break. It appears that sharp movements in the earnings-price ratio over this period (see Figure 21) are sufficient to stabilize the personal M2 demand equation, but whether this reflects a *causal* influence of this variable is, of course, open to question.

This effect of the earnings-price variable is quite surprising. The sharp decline in the earnings-price ratio in the 1982-83 period contributes to a considerable *increase* in money demand, rather than the decline that we associate with the consolidation period. However, the income elasticity is larger in the regression for personal M2 that includes the earnings-price ratio than in the regression that excludes it (2.0 in equation (P2) compared with 1.6 in equation (P1)). Consequently, the recession of the early 1980s is estimated to have had a stronger effect on the demand for M2 balances when the earnings-price variable is included in the estimated relationship.

Adding a wealth variable[50] to equation (P2) produced a positive coefficient for that variable but the effect of T90 and R90 became insignificant or incorrectly signed. This regression is shown as (P3).

We also investigated whether a proxy for the cost of financial intermediation (to capture households' inclination to shrink their balance sheets when the margin between rates on financial assets and liabilities widens) explained any of the variation in personal M2. Two measures were tried: the 5-year conventional mortgage rate (RM), and the differential between the 5-year mortgage rate and 5-year deposits at trust and mortgage loan companies (GIC).[51] When wealth was included as a regressor, each

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[50] This is the sum of the capital stock, the monetary base and the stock of government bonds.

[51] When this variable was added to the equation, the FPE criterion selected an order 4 equation. However, in the *level* equations presented below, an order 3 model is estimated because of degrees of freedom considerations (reduced to 11). In the first-differenced regressions, an order 4 model is used (i.e., order 3 on the first difference of all variables).

Table 10
Personal M2 Equations

	(P1)	(P2)	(P3)	(P4)	(P5)*
			Long-run elasticities		
Price	0.7	1.2	1.5	1.0^f	1.0^f
Income	1.6	2.0	2.1	1.5	1.2
Net interest rates	0.38	0.10	0.22	0.13	0.04
R90	0.21	-0.09		-0.11	-0.02
B90	0.17	0.34	0.22	0.47	0.23
T90		-0.15		-0.22	-0.16
EP		-0.11	-0.16	-0.08	-0.07
CSB	0.11	-0.12	-0.05	-0.12	-0.09
Wealth			1.8		
FDIFF				-0.09	
			Dynamics		
Constant	1.5 (4.1)	-5.1 (6.1)	-8.5 (9.3)	-2.0 (10.0)	0.00 (0.18)
Trend ($X\ 10^{-3}$)		-3.2 (3.4)	-10.5 (5.4)		
m					
1	0.85 (17.1)	0.37 (3.4)	0.23 (2.2)	0.70 (27.1)	0.55 (6.3)
2	0.23 (2.8)	0.45 (5.2)			
Price					
0			0.48 (5.1)		
1	0.11 (1.4)	0.49 (6.3)		0.30 (11.0)	0.45 (5.3)
Income					
0		0.35 (4.4)	0.24 (3.2)		
2	0.23 (5.3)			0.28 (3.7)	0.41 (4.3)
3		0.44 (4.3)	0.42 (4.1)	0.17 (2.1)	0.21 (1.9)
R90					
0	0.031 (5.0)	-0.038 (2.2)		-0.034 (3.6)	-0.01 (0.7)
B90					
0		0.063 (3.8)	0.039 (7.5)	0.064 (5.9)	0.039 (2.2)
3	0.026 (5.1)	0.075 (3.2)	0.031 (6.5)	0.076 (4.0)	0.112 (3.8)

(cont'd)

Table 10 (cont'd)
Personal M2 Equations

	(P1)	(P2)	(P3)	(P4)	(P5)*
			Dynamics		
T90					
0				-0.014 (1.8)	
1				0.024 (3.3)	
2				-0.076 (3.9)	
3			-0.061 (2.6)		-0.088 (3.0)
Earnings-price ratio					
0		-0.031 (5.2)	-0.036 (5.7)	-0.025 (6.5)	-0.026 (2.9)
1		-0.011 (1.9)			-0.298 (3.3)
2					0.039 (4.2)
3			-0.016 (4.2)	-0.022 (2.50)	
CSB					
0	-0.073 (3.9)	-0.120 (9.6)	-0.081 (8.9)	-0.117 (12.5)	-0.102 (5.3)
1	0.044 (2.2)	0.070 (7.0)		0.082^c	0.055 (3.1)
3	0.044 (3.5)		0.064 (4.4)		
Wealth					
0			0.56 (4.4)		
FDIFF					
0				-0.027 (2.0)	
2					
3					
$\bar{R}^2$	0.999	0.999	0.999	0.999	0.908
S.E.E.	0.00483	0.00315	0.00314	0.00311	0.00458
D.W.	2.0	2.5	2.5	2.3	2.6

* = first-difference equation

c = constrained

FDIFF = differential of 5-year mortgage rate and 5-year deposits at trust and mortgage loan companies.

Note: All equations are estimated over the 1975Q1-1987Q4 period. The estimates of the dynamics are the coefficients from the regressions: $A(L)m = G(L)X\beta$ where all the lag polynomials are of order 3, $A(0) = 1$, and X includes the variables listed in the table. The long-run elasticities (or estimate of the cointegrating vector) are given by: $m = A(1)^{-1}G(1)X\beta$.

Figure 21
Earnings-Price Ratio

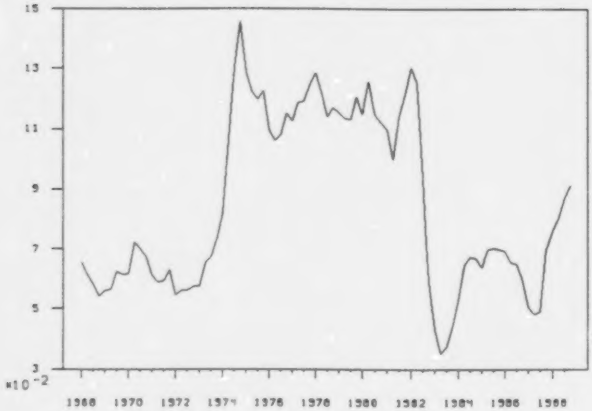
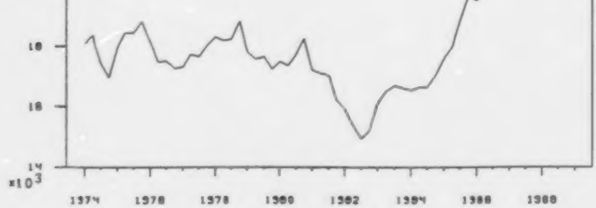


Figure 22
Real Non-Personal M2



of the measures tended to have a marginally significant negative effect. When wealth was omitted, the financial intermediation variable frequently became insignificant.

Equations (P2) and (P3) contain a linear time trend. To assess the impact of this variable, the next regression omits it. Without the trend, the wealth elasticity was negative; that variable was consequently dropped from the regression. T90 was significant in this specification. Of the two proxies for the cost of financial intermediation, the one using the differential between the mortgage rate and the GIC rate yielded better results. The long-run price elasticity was insignificantly different from one, so that constraint was imposed. In addition, in this specification, the (nonlinear) restriction that CSBs had a once-and-for-all effect could not be rejected and was imposed. This regression is shown as (P4).

In the equation for personal-sector deposits, as for the currency equation, there is some question as to whether the error term is stationary (even after a deterministic time trend is included). To address this issue, Augmented Dickey-Fuller tests for cointegration were performed on static regressions that incorporated the variables that had been included in regressions (P1) to (P4). While we may be able to say little about the significance of the estimated coefficients in these static regressions, it is interesting to compare these regressions with the results presented earlier from the dynamic specifications:

> In the cointegrating (CI) regressions, R90 tends to have a negative sign in contrast with the distributed-lag (ADL) regressions where the effect sometimes switches signs. B90 is positive in three of the four CI regressions but is positive in all the ADL regressions. T90 consistently has the wrong sign in the CI regressions.

- The output elasticities in the CI regressions that exclude wealth are very close to the estimates from the ADL regressions. But if wealth is added to the CI regression, the coefficient on real GDP falls sharply.
- The wealth elasticity is similar in both the CI and ADL regressions.
- The earnings-price ratio has a persistently negative effect, no matter which variables are included in the CI or ADL regressions.

Tests using the residuals of these CI regressions could not reject the null hypothesis of no cointegration. This result is even less surprising than for the currency equations given the additional number of regressors in these equations and the corresponding increase in the critical values of the test as well as the shorter sample period.

Consequently, the equations were also estimated in first-differenced form with up to three lags. The differenced equation was allowed to have a constant but no linear trend term. Preliminary results indicated that when the wealth variable was included, the real GDP variable had a *negative* long-run effect; consequently, the wealth variable was dropped.[52] The two financial intermediation variables (the mortgage rate alone or its spread compared to the 5-year GIC rate at TMLs) were also insignificant or had the wrong sign. The long-run price effect was not significantly different from one and this constraint was imposed. These results are shown in equation (P5). In this regression, the income elasticity is 1.2 and the net interest rate elasticity is again positive. The hypothesis (analogous to that discussed in the aggregate M2 equation) that the effect of CSBs in the fourth-quarter sales period differed from that in the rest of the year found no statistical support.

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[52] Regressions excluding real GDP but including wealth were also tried but gave higher standard errors.

The long-run elasticities of equations (P1) to (P5) are shown in Table 10. While these equations give different estimates for some parameters, in many respects the models yield quite similar implications.

The levels equations with time trends generally give long-run price elasticities considerably and significantly greater than one; however, when the time trend is excluded, or in the first-difference regressions, the long-run price elasticity does not differ significantly from one. The estimates of the long-run income elasticities are fairly similar (except when wealth is also included). The role of the wealth variable is more uncertain: while reinforcing the role of real GDP in some level equations, in some preliminary specifications in the growth-rate equations, it often resulted in a negative long-run elasticity for real GDP.[53]

B90 has a positive effect in all equations but the anticipated negative effect of T90 is observed less frequently. The net interest rate elasticity is always positive, but small.

While in some regressions a proxy for financial intermediation appears to play a role, this result is not very robust.

The earnings-price ratio has an important negative effect in all distributed-lag regressions (similarly, in the cointegrating regressions).[54] The estimates of the long-run elasticity of CSBs are generally quite similar, though the dynamics differ considerably in terms of whether the response is immediate, subsequently reversed, or whether the effect builds over time.

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[53] When the wealth variable is substituted for the real GDP variable, the explanatory power is lower than in the regression that includes GDP and excludes wealth.

[54] The strength of this relationship is somewhat astonishing. For example, if the earnings-price ratio is dropped from equation (P5), the standard error of the regression increases by more than 40 per cent. The equation without that variable also exhibits considerably slower adjustment.

In equations (P4) and (P5), an additional check for stability during the consolidation period was provided by including a consolidation-period dummy as a regressor (for the period 1982Q3 to 1983Q4). The coefficients on that variable were insignificant in both equations. Finally, dummies for postal strikes were also included in the two equations but were found to be insignificant.

The long-run elasticities of equations (P4) and (P5) are quite similar. Given the somewhat better fit of equation (P4), it is chosen for the components model.

4.5 The non-personal M2 equation

A second-order (as suggested by the FPE) loglinear model was estimated over the 1975Q1-1987Q4 period using real GDP, its deflator and R90 as a starting point. The time trend was found to be insignificant and the long-run price elasticity was found not to differ from one. Equation (N1) in Table 11 imposes these constraints. Equation (N1) has large long-run elasticities: 3.1 for output and -1.5 for the interest rate. A plot of real non-personal M2 balances (Figure 22) shows that between 1974 and mid-1982, real balances exhibited a declining trend, despite the substantial rise in income that occurred during that period. This is consistent with the sharp rise in velocity over the same period and should contribute to a small income elasticity. Between 1982 and 1987, however, with the increased availability of interest-bearing non-personal notice accounts, real balances almost doubled. The much slower rise in income over this period produces the high elasticities of equation (N1). When the same equation is estimated for the 1975Q1-1982Q4 period, the elasticities are very different. In the unconstrained regression, equation (N2), the long-run price elasticity is significantly different from one, with long-run elasticities of 0.6 for price, 0.7 for output, and -0.12

Table 11
Non-Personal M2

	(N1)	(N2)	(N3)	(N4)	(N5)	(N6)	(N7)	(N8)
				Long-run elasticities				
Price	1.0^c	0.6	1.0^c	1.0^c	1.0^c	1.0^c	1.0^c	1.0^c
Output	3.1	0.7	1.6	1.3	1.5	1.3	0.7	0.7
Net interest rates	-1.5	-0.1	-0.4	-0.2	-0.3	-0.2	-0.0	-0.1
R90	-1.5	-0.1	-0.4	-0.2	-1.4	-2.2	-0.0	0.1
RPRIME					1.1	2.0		-0.1
OFT			-0.5	-0.5	-0.5	-0.7	-0.4	-0.4
				Dynamics				
Constant	-1.4	0.9	-0.7	-0.6	-0.6	-0.1	5.7	5.6
	(3.3)	(0.5)	(1.7)	(0.4)	(1.3)	(0.1)	(6.5)	(6.4)
m	0.95	0.42	0.83	0.58	0.83	0.88		
1	(19.1)	(2.8)	(13.5)	(4.9)	(13.7)	(19.6)		
p	1.10	1.91	1.58	1.78	1.48	1.00^c	1.00^c	1.00^c
0	(2.9)	(3.3)	(4.1)	(3.3)	(3.8)			
2	-1.05	-1.55	-1.40	-1.36	-1.31	-0.88^c		
	(3.0)	(3.0)	(4.1)	(2.6)	(3.7)			
y	0.17	0.38	0.28	0.54	0.26	0.16	0.72	0.72
0	(3.2)	(2.0)	(4.5)	(2.5)	(4.0)	(4.5)	(11.0)	(11.0)
R90	-0.123	-0.069	-0.109	-0.095	-0.24	-0.26	-0.047	0.06
0	(6.2)	(2.5)	(5.7)	(3.6)	(3.8)	(4.2)	(1.1)	(0.3)
2	0.043		0.039					
	(2.3)		(2.3)					
RPRIME					0.18	0.25		-0.130
0					(2.4)	(3.4)		(0.6)
OFT			-0.094	-0.198	-0.088	-0.085	-0.449	-0.438
			(3.0)	(2.5)	(2.8)	(3.0)	(7.0)	(6.6)
$\bar{R}^2$	0.996	0.982	0.996	0.983	0.996	0.997	0.765	0.786
S.E.E.	0.0199	0.0215	0.0184	0.0205	0.0183	0.0169	0.0765	0.0547
D.W.	1.9	1.4	2.1	2.1	2.1	2.2	0.18	0.23

Note: All equations are estimated over the 1975Q1-1987Q4 period except equations (N2) and (N4) which are estimated over the 1975Q1-1982Q4 period. The estimates of the dynamics are the coefficients from the regressions: $A(L)m = G(L)X\beta$ where all the lag polynomials are of order 2, $A(0)=1$, and X includes the variables listed in the table. The long-run effects (or estimate of the cointegrating vector, except that the constant is not reported) are given by: $m = A(1)^{-1}X\beta$.

for the 90-day commercial paper rate. When a long-run price elasticity of one is imposed, the output effect becomes slightly negative and insignificant.

We believe that much of the slowness in the growth of non-personal M2 before 1983 is related to the effects of financial innovation. The introduction of cash management accounts, beginning in the mid-1970s, permitted non-interest-bearing current account balances to be reduced and funds to be deposited overnight in the money market. Such overnight deposits are a component of the category "other fixed-term deposits" which are part of M3 but are excluded from M2. Subsequently, in the early 1980s, in another phase of financial innovation related to cash management practices, the payment of interest on notice accounts (included in M2) induced a shift back towards non-personal M2. If such financial innovations account for the slow growth of non-personal M2 in the 1970s and the subsequent pickup in growth in the early 1980s, then a regression of the sum of non-personal M2 and the category "other fixed-term deposits," which internalizes this shift, might be more stable and should have a significant income elasticity over that period. There is some support for this view: over the 1975-82 period, the regression of the sum of non-personal M2 plus other fixed-term deposits has an income elasticity of 1.3. Over the entire 1975-87 period, the income elasticity is only 0.4, but remains significantly different from zero.

Because this financial innovation is a "technological" phenomenon, we may not be able to capture its effects by including an interest rate variable for these overnight deposits; consequently, the *quantity* of other fixed-term deposits - the category into which the substitution from non-personal M2 was directed[55] in the 1970s - was included in the regression for non-personal M2. With "other fixed-term deposits" (deflated by PGDP and denoted OFT) included in the regression, the income elasticity was sharply reduced.[56] Over the full 1975 to 1987 period, equation (N3) has long-run elasticities of 1.6 for output, -0.4 for interest rates and -0.5 (about $0.60 on non-personal M2 for every $1 increase in OFT, given 1987 levels) for the stock of other fixed-term deposits. The long-run price elasticity was constrained to one, a constraint accepted by the data.

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[55] Funds were diverted into very short-term deposits. However, data on such deposits cannot be separated from data on total non-personal fixed-term deposits.

The estimate of the income elasticity obtained in a regression over the shorter 1975-82 period, equation (N4), is similar with long-run elasticities of 1.3 for output, -0.23 for R90 and -0.5 for OFT.[57]

The rate paid on interest-bearing current accounts and on notice accounts included in non-personal M2 is frequently tied to the prime rate on business loans. Consequently, in the absence of any direct measure of the own rate on non-personal M2, the prime rate may provide some information about movements in that rate. Inclusion of the prime rate in the non-personal M2 equation (equation (N5)) does indeed produce a positive effect for that variable. The long-run income elasticity is 1.5, the long-run elasticity with respect to R90 is -1.4 and for RPRIME it is 1.1, for a net interest rate elasticity of -0.3. The long-run elasticity with respect to OFT is -0.5. Equation (N5) passes a rolling Chow test over the entire sample period.

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[56] In addition to the substitution between non-personal M2 and "other fixed-term deposits" induced by financial innovation, it is possible that, even when financial innovation is not operating, changes in the rate paid on other fixed-term deposits could induce substitution between non-personal M2 and OFT. In regressions that exclude OFT, however, the 90-day money market CD rate, a proxy for the rate paid on OFTs, is so collinear with R90 (the correlation coefficient is 0.97 over the 1974-87 period) that separate identification of an effect of this rate was impossible. Furthermore, R90 was found to be a more informative rate than the rate paid on 90-day money market rates and so was retained as the interest rate variable. A longer-term interest rate, the rate on provincial government bonds, was also tried but proved either insignificant or significantly positive in the regression.

[57] When lagged, rather than contemporaneous OFT is used as a regressor, the results are similar.

Dummies for postal strikes (in 1975Q4 and 1978Q4) were added to equation N5 and had a marginally significant effect; however, there was almost no effect on the estimated long-run elasticities, so these variables were omitted.[58]

The gradual adjustment of non-personal M2 to variations in OFT is difficult to justify on theoretical grounds. Nevertheless, a likelihood-ratio test of the nonlinear constraint of once-and-for-all adjustment was strongly rejected. The empirical evidence, then, is consistent with a view that an increase in OFT is initially met by reducing assets additional to non-personal M2 balances; later, those other balances may be partly restored with non-personal M2. Equation (N5) indicates that, in 1988, a $1 increase in other fixed-term deposits was consistent with a $0.58 decrease in non-personal M2.

The possibility that price adjustment is instantaneous rather than distributed over time as in all the equations presented above was also tested but was rejected. The rejection is not surprising given the considerable overshooting of money to changes in price evident in the equations.

This overshooting, however, seems specific to the measures used above for the price series - i.e., the deflator for GDP. If the GDP-based measures of output and price are replaced by gross private business product (GPP),[59] the pattern is quite different and, indeed, the hypothesis of instantaneous adjustment is not rejected and is imposed below in equation (N6). In this regression, the long-run income elasticity is 1.3. The net interest rate elasticity is again -0.2. The long-run elasticity with respect to OFT is -0.7, indicating that, at 1988 levels, a $1 increase in OFT was consistent with a $0.75 decrease in non-personal M2.

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[58] Equations with postal strike dummies, however, did not pass a rolling Chow test and suggested a break in late 1981 or early 1982. This presumably occurs because the reduction in the residual variance when dummies are used to explain the residuals of the strike quarters makes the test more powerful.

[59] Gross private business product (GPP) excludes agriculture and non-commercial businesses. Final sales were also tested as a scale variable, but GPP gave better results.

The cointegrating regressions corresponding to (N5) and (N6) are presented in equations (N7) and (N8). Augmented Dickey-Fuller tests of the residuals of (N7) and (N8) could not reject a unit root. Equations (N7) and (N8) both suggest an income elasticity somewhat lower than that estimated in earlier equations. In (N7) the interest rate effect is similar to the corresponding distributed-lag equations, though in equation (N8) the interest rate signs are reversed.

Equations were also estimated in first-difference form, but were not very satisfactory. The long-run price elasticity generally was significantly different from one and the income elasticity, though positive (usually in a range of 0.4 to 0.5), was frequently insignificantly different from zero. Only the interest rate effect remained consistently significant. Furthermore, the regressions explained less than 30 per cent of the variation in the quarterly rate of growth of non-personal M2. Consequently, for the disaggregated M2 model, it was decided to use an equation in the level of non-personal M2, equation (N6).

4.6 Simulation, forecasting and other properties of the chosen equations

The equations chosen for the disaggregated M2 model consist of equation (C4) for the currency equation, (P4) for the personal M2 equation and equation (N6) for non-personal M2. The currency equation was estimated in first-difference form and the personal and non-personal M2 equations were estimated in levels.

Table 12 shows the long-run income and interest rate elasticities of the components of the system and the resulting elasticity for aggregate M2 (using

1988 shares of the components).[60] Note that the resulting elasticities of aggregate M2 will vary over time as the shares of the three components of M2 change.[61] Figures 23 to 28 illustrate the dynamics of the disaggregated system. The graphs trace out over time the effects on the components, and the corresponding effect on aggregate M2, of one per cent shocks to all the explanatory variables in the system.

Table 12
Long-Run Elasticities

	Income	Interest rate
Currency	0.7	-0.27
Personal M2	1.5	0.13
Non-personal M2	1.3	-0.14
Total M2	1.4	0.05

Dynamic and static simulations were performed on all equations. The root-mean-squared errors (RMSE) of the simulations are shown in Table 13.

Graphs of the actual and simulated levels (from a dynamic simulation) and rates of growth are presented in Figures 29 to 34. The currency equation appears to perform well. When the dependent variable is taken to be the rate of growth of currency, the RMSE of the late-sample and post-sample period is actually smaller than the RMSE calculated over the 1969Q1-1985Q4 period. The substantial increase in the per cent RMSE for the *level* of currency balances is expected, given the first-difference specification of that equation. Personal M2 growth has a fairly low RMSE for the earlier sample period, but the RMSE rises considerably in the 1986Q1-1989Q1 subperiod and the equation consistently underpredicts growth in 1988 (Figure 32). The per cent RMSE for the non-personal M2 equation is considerably higher than for the other two equations, but is roughly the same in the later subperiod as in the 1975-85 period. Still, the equation shows considerable overprediction of the level of non-personal M2 in the last two years of the period.

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[60] The shares are 8.3 per cent for currency, 74.7 per cent for personal M2 and 17.0 per cent for non-personal M2.

[61] However, over the sample period, the changes in the aggregate income and interest rate elasticities are very small.

Table 13
Root-Mean-Squared Errors

		Static (%)	Dynamic (%)
Currency			
Rate of growth	1969Q1-1985Q4	0.46	0.62
	1986Q1-1989Q1	0.26	0.31
Level	1969Q1-1985Q4	0.46	5.47
	1986Q1-1989Q1	0.26	1.41
Personal M2			
Rate of growth	1975Q1-1985Q4	0.27	0.31
	1986Q1-1989Q1	1.28	0.81
Level	1975Q1-1985Q4	0.27	0.32
	1986Q1-1989Q1	1.28	2.77
Non-personal M2			
Rate of growth	1975Q1-1985Q4	1.74	1.83
	1986Q1-1989Q1	1.73	1.70
Level	1975Q1-1985Q4	1.74	2.31
	1986Q1-1989Q4	1.73	3.19

Figure 23
Price Shock

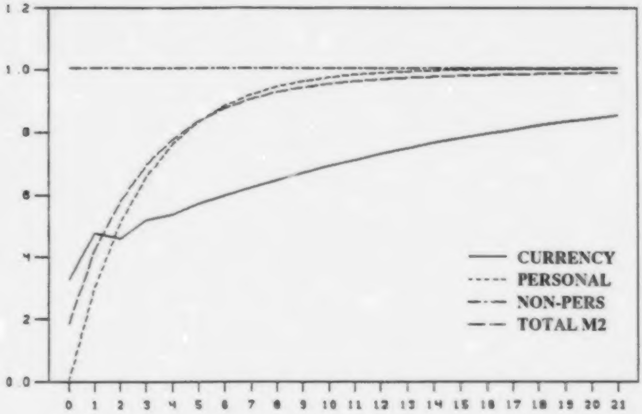


Figure 24
Output Shock

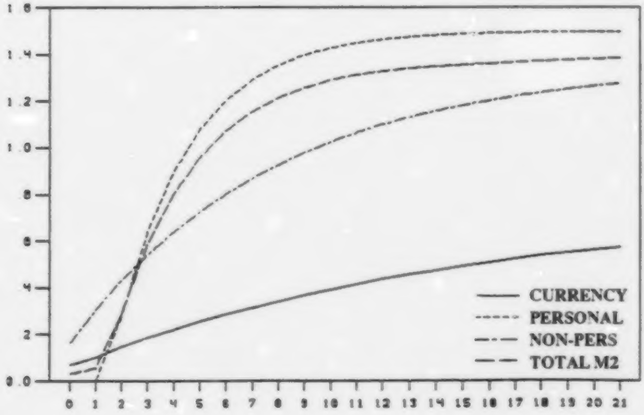


Figure 25

Interest Rate Shock

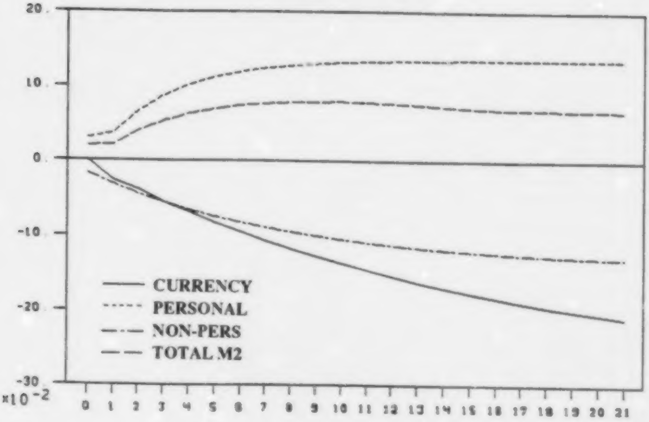


Figure 26

Earnings-Price Ratio Shock

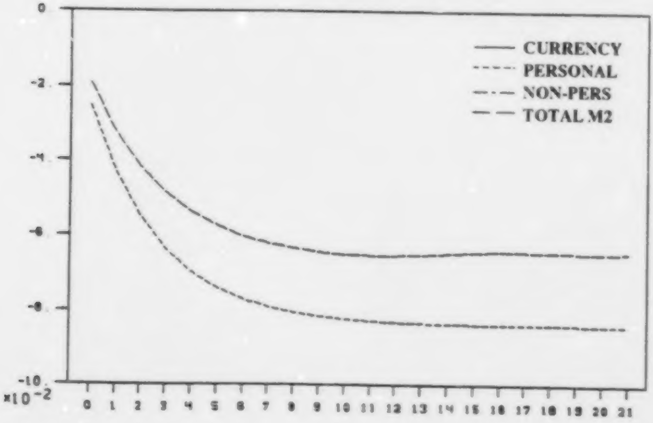


Figure 27
CSB Shock

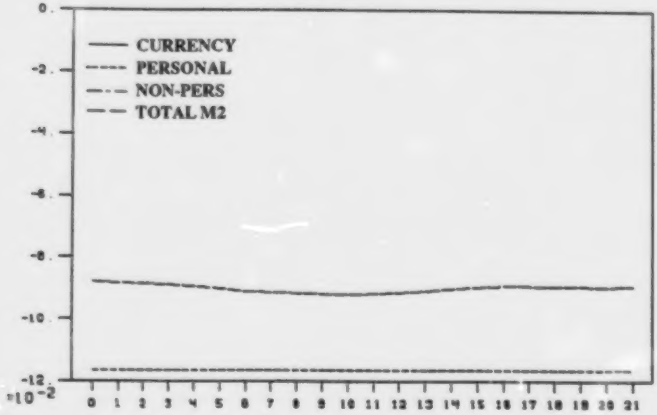


Figure 28
OFT Shock

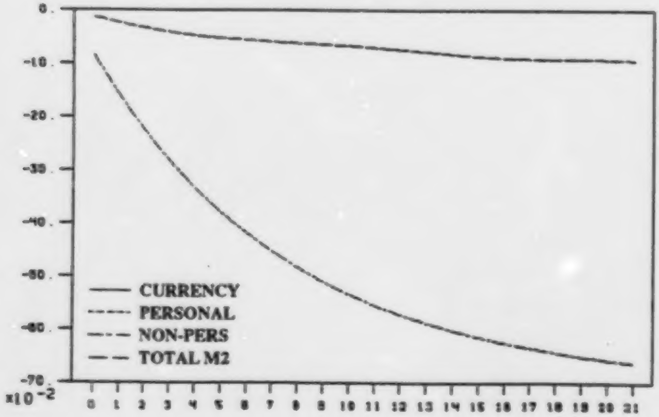


Figure 29
Currency - Level

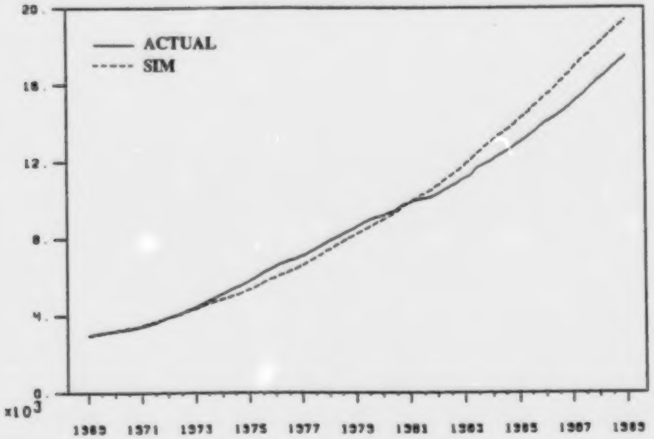


Figure 30
Currency - Quarterly Growth

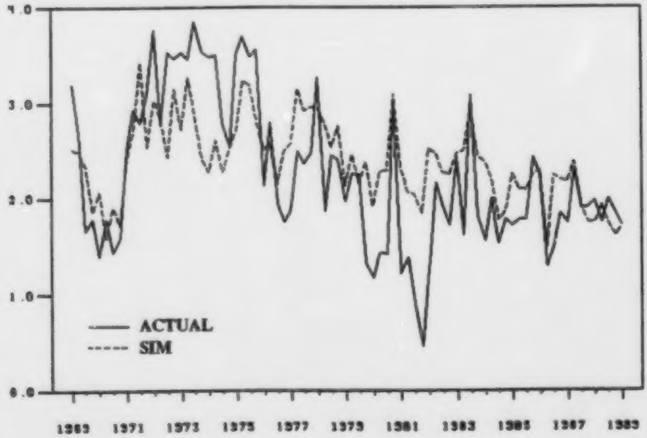


Figure 31
Personal M2 - Level

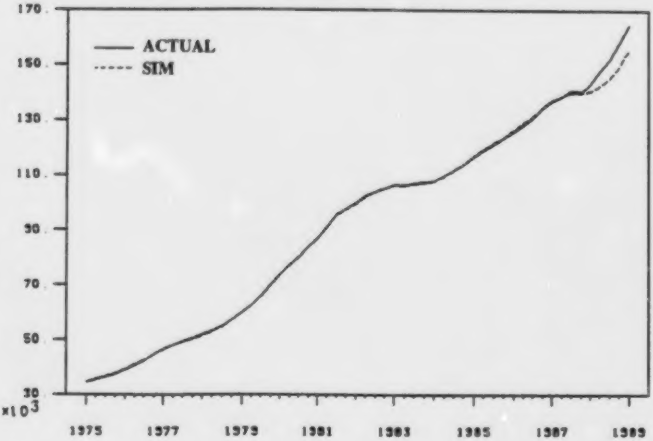


Figure 32
Personal M2 - Quarterly Growth

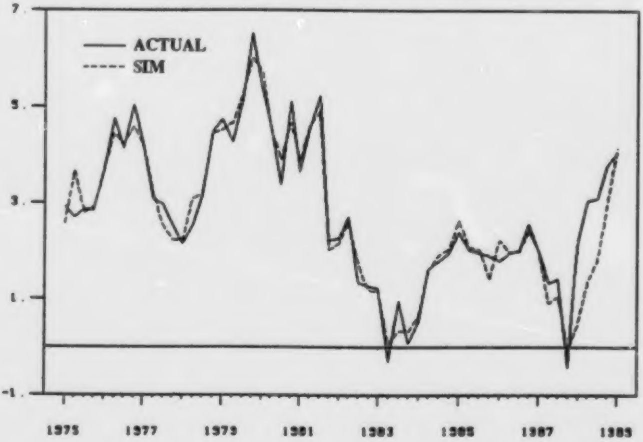


Figure 33
Non-Personal M2 - Level

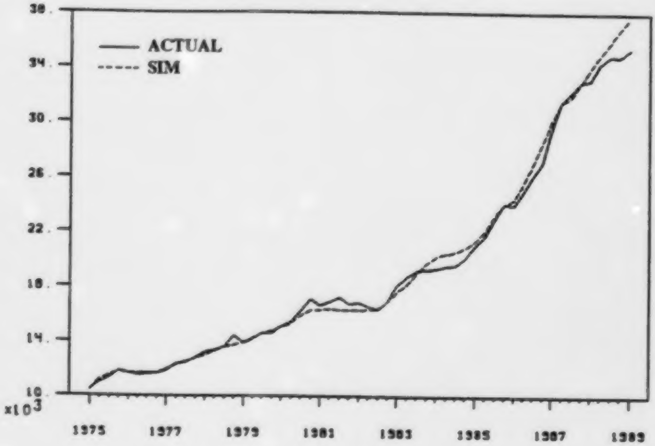
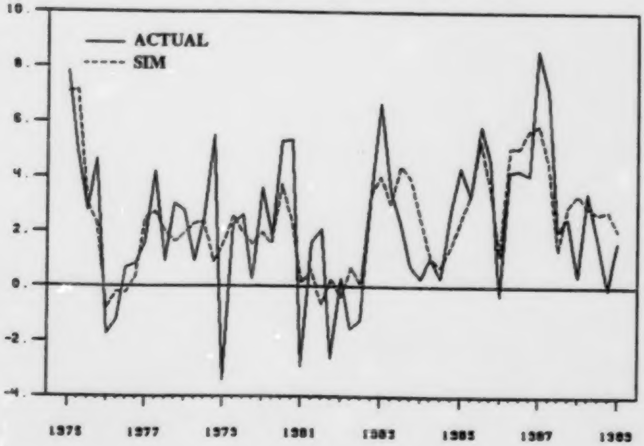


Figure 34
Non-Personal M2 - Quarterly Growth



The simulation properties of the disaggregated system of equations were compared next to the tracking ability of a monthly aggregate M2 equation, similar to that presented in Section 2. The aggregate M2 equation uses *net* rather than *gross* M2 as a dependent variable; consequently, that equation was re-estimated over the sample period 1975:01 - 1987:12 (the sample period corresponding to that of the disaggregated equations) using gross M2 as the dependent variable. The simulated values from the monthly equations were then collapsed to a quarterly frequency. The comparison with the components model is presented in Table 14 below and in Figures 35 and 36. Figure 37 shows the one-period forecast errors in the rate of growth, while Figure 38 shows the errors from a dynamic simulation of the level of M2. The growth-rate specification of the aggregate M2 equation can explain the large size of the level errors.

Table 14
Simulation Properties of the Aggregate M2 Equation and of the Disaggregated Model

		RMSE (%)
Aggregate M2 equation		
Static		
Growth rate	1975Q1-1985Q4	0.36
	1986Q1-1989Q1	0.30
Dynamic		
Level	1975Q1-1985Q4	1.38
	1975Q1-1989Q1	1.44
Disaggregated model		
Static		
Growth rate	1975Q1-1985Q4	0.58
	1986Q1-1989Q1	0.55
Dynamic		
Level	1975Q1-1985Q4	1.10
	1975Q1-1989Q1	1.35

Figure 35
Dynamic Simulations - Level

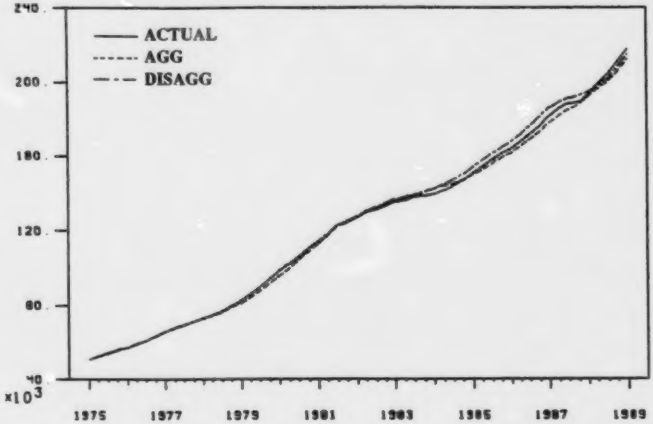


Figure 36
Dynamic Simulations - Growth Rate

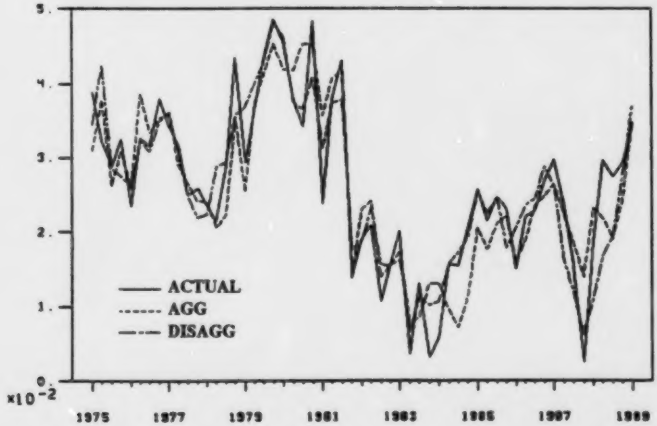


Figure 37
Growth Rate - Static Simulation Errors

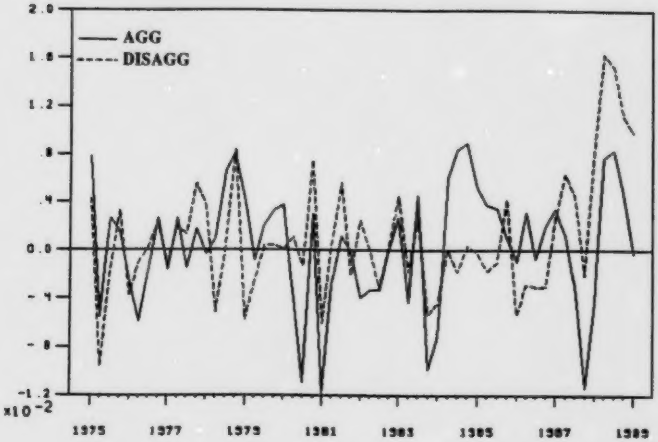
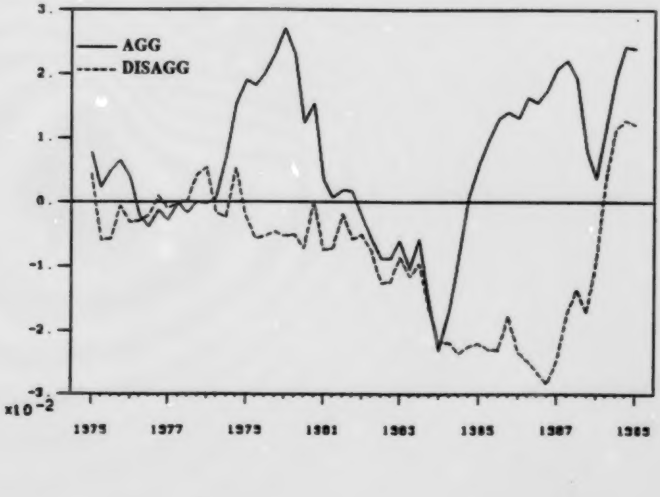


Figure 38
Dynamic Simulation Errors - Per Cent



The RMSE for the growth rate of gross M2 using the disaggregated system is 0.58 percentage points for the earlier period and is virtually the same in the later period. These numbers are considerably larger than those for the aggregate M2 equation (which is not surprising given that the aggregate M2 estimates are chosen to minimize the squared growth-rate residuals, whereas the estimates of the two major components of the disaggregated system are chosen to minimize the *level* residuals). The per cent RMSEs for the dynamic simulation of the level of M2 in the disaggregated system are well below those of the aggregate M2 equations reflecting, in part, the lesser importance of the nonstationary component in the disaggregated system (only the currency equation is specified in a nonstationary manner).

4.7 A summary

The disaggregated model estimated in Section 4 addresses a number of issues that have been raised concerning aggregate M2. With respect to the consolidation-period shift, with the disaggregated model we find that the personal-sector equation (where the shift should most likely be found if our interpretation is correct) is stable without the use of a consolidation-period dummy as long as the earnings-price ratio is included. The earnings-price ratio, a variable whose effect on aggregate M2 was found in previous studies to be significant at times, is found to have a consistently significant negative impact on personal M2 over the shorter estimation period. Wealth, though significant in some regressions, does not add greatly to the predictive power of the equation and, in some regressions, has the wrong sign. The 90-day rate at trust and mortgage loan companies, though insignificant or incorrectly signed in some regressions, has a significant negative effect in the equation chosen for the disaggregated model.

The very low interest rate elasticity of the aggregate M2 equation appears to result from the influence of personal-sector deposits. Both currency and non-personal-sector deposits have negative interest rate elasticities, whereas personal M2 was found to have a significantly positive net interest rate elasticity.

We have more confidence in the estimates of the personal-sector and currency equations than in the non-personal-sector equations. The estimates of the long-run elasticities of demand in the personal M2 equation are quite robust whether the estimation is done in levels or first differences. The currency equation is a standard transactions-type equation that yields estimates consistent with a Baumol-type model. Estimates of the non-personal M2 equation, on the other hand, vary significantly depending on whether a distributed-lag, static-cointegrating or first-difference specification is used.

For non-personal M2, it appears useful to control for shifts between non-personal M2 and "other fixed-term deposits" to obtain sensible estimates of the elasticities. This adjustment for "other fixed-term deposits" is ad hoc and the gradual adjustment of non-personal M2 to changes in this variable is somewhat suspicious. Caution is recommended in projecting the effect of future changes in this variable on non-personal M2.

The properties of total M2, obtained by aggregating the component equations, appear reasonable. The income elasticity of total M2 is considerably larger than in the aggregate M2 equations presented in Section 2, for example, because both personal and non-personal M2 were found to have long-run elasticities exceeding one (although the static-cointegrating regressions suggest a somewhat smaller income elasticity for non-personal M2). Currency demand, on the other hand, shows significant economies of scale. Nevertheless, over the sample period, the relative importance of the three components does not change enough to explain any considerable variation in aggregate M2.

The forecasting properties of the component system seem reasonable and are similar to those of the aggregate M2 equation with a consolidation-period dummy. The disaggregated system has the advantage that the consolidation-period decline in M2 holdings is captured endogenously rather than by a dummy variable.

Appendix 1

Notation and Data Sources

M2	monetary aggregate M2, average of Wednesdays (CANSIM B1630)
M2+	monetary aggregate M2+, average of Wednesdays (CANSIM B1633)
Currency	currency outside banks, average of Wednesdays (CANSIM B1604)
Personal M2	personal chequing accounts (B486) + chequable personal savings accounts (B452 from 1968:01 to 1981:12 and B484 + B485 from 1982:01 to 1989:12) + daily interest savings accounts (B480) + fixed-term deposits (B454) + adjustments (Bank of Canada)
Non-personal M2	current accounts (B487) + non-personal chequable notice deposits (B472) + non-personal non-chequable notice deposits (B473) - interbank deposits (B2035) + adjustments (Bank of Canada)
Prices	GDP deflator (CANSIM D20337), quarterly national accounts data interpolated to monthly frequency
Real income	GDP in constant dollars, monthly (CANSIM I32026)
Final sales	real income minus change in farm and business inventories
CON	consumer spending, constant dollars (CANSIM D20131)
PCON	deflator for consumer spending (CANSIM D20338)
YDP	personal disposable income (CANSIM 20111)
EP	earnings-price ratio (inverse of CANSIM B4246)
Wealth	capital stock in constant dollars + monetary base + government bonds deflated by GDP deflator (Bank of Canada)
R90	90-day prime corporate paper rate, average of Wednesdays (CANSIM B113858)
B90	interest rate on 90-day fixed-term deposits of personal sector at chartered banks, average of Wednesdays (Bank of Canada)

(cont'd)

Notation and Data Sources (cont'd)

T90	interest rate on 90-day fixed-term deposits of personal sector at trust and mortgage loan companies, average of Wednesdays (Bank of Canada)
RMTG	chartered bank typical 5-year mortgage rate (CANSIM B113872)
GIC5	interest rate on 5-year GICs at trust and mortgage loan companies (CANSIM B113875)
RSDB	interest rate on non-chequable savings deposits, average of Wednesdays (CANSIM B113872)
CSBs	stock of Canada Savings Bonds, average of Wednesdays (CANSIM B2406) divided by GDP deflator
DUM82-84	variable that has a value of 1 between July 1982 and November 1984 and 0 in other periods
D83	variable that has a value of 1 in May and -1 in June 1983, and 0 in other periods
D74A	postal strike variable, equal to 1 in April and -1 in May 1974, and 0 in other periods
D74B	postal strike variable, equal to 1 in May and -1 in June 1974, and 0 in other periods
D75A	postal strike variable, equal to 1 in October and -1 in November 1975, and 0 in other periods
D75B	postal strike variable, equal to 1 in November and -1 in December 1975, and 0 in other periods
D75C	postal strike variable, equal to 1 in December 1975 and -1 in January 1976, and 0 in other periods
D78B	postal strike variable, equal to 1 in November and -1 in December 1978, and 0 in other periods
D81A	postal strike variable, equal to 1 in July and -1 in August 1981, and 0 in other periods
D81B	postal strike variable, equal to 1 in August and -1 in September 1981, and 0 in other periods

Appendix 2

Estimated Demand Equations for M2 and M2+
Sample period: 1970:01 to 1987:12

		M2		M2+	
Explanatory variable		Coefficient	t-statistic	Coefficient	t-statistic
Constant		**0.0032**	**6.555**	**0.0033**	**9.259**
	lag				
Prices	0	0.076	0.865	0.161	2.578
	1	0.110	2.402	0.155	4.740
	2	0.129	8.740	0.144	13.659
	3	0.136	20.133	0.129	26.971
	4	0.132	6.545	0.112	7.851
	5	0.119	4.472	0.093	4.934
	6	0.102	3.633	0.074	3.754
	7	0.080	3.179	0.055	3.115
	8	0.057	2.895	0.038	2.714
	9	0.036	2.699	0.022	2.439
	10	0.017	2.557	0.010	2.239
	11	0.004	2.449	0.002	2.087
	12	0.000	C	0.000	C
	Sum	**1.000**	C	**1.000**	C
Real income	0	0.119	2.764	0.129	4.049
	1	0.090	3.663	0.114	6.416
	2	0.067	2.969	0.098	6.113
	3	0.050	2.031	0.084	4.686
	4	0.039	1.588	0.070	3.933
	5	0.031	1.429	0.057	3.565
	6	0.026	1.340	0.044	3.116
	7	0.023	1.124	0.033	2.243
	8	0.021	0.871	0.023	1.362
	9	0.018	0.700	0.015	0.790
	10	0.015	0.599	0.008	0.455
	11	0.009	0.541	0.003	0.255
	12	0.000	C	0.000	C
	Sum	**0.508**	**3.794**	**0.681**	**6.880**

(cont'd)

Estimated Demand Equations for M2 and M2+ (cont'd)
Sample period: 1970:01 to 1987:12

		M2		M2+	
Explanatory variable		Coefficient	t-statistic	Coefficient	t-statistic
	lag				
R90	0	-0.0006	-1.342	-0.0027	-2.050
	1	-0.0007	-2.711	-0.0006	-3.154
	2	-0.0006	-2.648	-0.0005	-2.834
	3	-0.0004	-1.819	-0.0004	-2.164
	4	-0.0002	-0.898	-0.0003	-1.755
	5	0.0000	0.170	-0.0002	-1.377
	6	0.0002	1.131	-0.0002	-0.933
	7	0.0003	1.672	-0.0001	-0.562
	8	0.0002	1.892	0.0000	-0.327
	9	0.0000	C	0.0000	C
	Sum	**-0.0017**	**-1.236**	**-0.0027**	**-2.918**
(R90-B90)	0	-0.0012	-1.245	-0.0014	-2.291
	1	-0.0014	-1.850	-0.0017	-3.828
	2	-0.0015	-2.196	-0.0019	-5.041
	3	-0.0016	-2.206	0.0020	-5.264
	4	-0.0016	-2.078	-0.0019	-4.945
	5	-0.0014	-1.938	-0.0018	-4.557
	6	-0.0012	-1.818	-0.0015	-4.231
	7	-0.0009	-1.722	-0.0011	-3.976
	8	-0.0005	-1.645	-0.0006	-3.776
	9	0.0000	C	0.0000	C
	Sum	**-0.0115**	**-2.228**	**-0.0144**	**-5.285**
(B90-T90)	0	0.0007	0.472		
	1	0.0013	1.199		
	2	0.0018	1.772		
	3	0.0022	1.101		
	4	0.0025	2.323		
	5	0.0026	2.531		
	6	0.0027	2.752		
	7	0.0027	2.964		
	8	0.0026	3.097		
	9	0.0025	3.069		
	10	0.0023	2.877		

(cont'd)

Estimated Demand Equations for M2 and M2+ (cont'd)
Sample period: 1970:01 to 1987:12

		M2		M2+	
Explanatory variable		Coefficient	t-statistic	Coefficient	t-statistic
	lag				
(B90-T90)	11	0.0021	2.620		
	12	0.0020	2.403		
	13	0.0018	2.273		
	14	0.0017	2.171		
	15	0.0016	1.878		
	16	0.0016	1.372		
	Sum	0.0352	3.062		
CSBs		-0.124	-13.849	-0.092	-13.852
DUM82-84		-0.0023	-2.825	-0.0027	-4.618
D74A		0.008	2.587	0.004	1.889
D74B		0.014	4.532	0.008	3.527
D75A		0.006	1.947	0.004	2.009
D75B		0.010	2.651	0.007	2.825
D75C		0.098	2.727	0.006	2.573
D78		0.011	4.137	0.006	3.343
D81A		0.007	2.507	0.005	2.431
D81B		0.005	1.560	0.005	2.120
D83		-0.009	-3.422	-0.005	-2.911
$\bar{R}^2$		0.659		0.683	
S.E. ($X 10^{-2}$)		0.369		0.275	
D.W.		2.010		1.571	

C = constrained

Note: Prices, real income and CSBs are first differences of natural logarithms. Interest rates are first differences of levels.

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Commentary

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by Apostolos Serletis

Caramazza et al. report the results of three approaches to modelling money demand that explore the implications of alternative ways to model dynamics. The problem is that the three different approaches do not share a common platform and, as a result, it is difficult to make comparisons and draw conclusions regarding their validity. I shall, therefore, in my discussion, offer a few constructive criticisms with the hope of encouraging the authors to pursue this line of research further.

In Section 2 of the paper, the demand for M2 and M2+ is modelled in growth-rate form using monthly data and Almon lag structures for the explanatory variables to capture the dynamics. Abstracting from statistical considerations, the model fails to capture the response of money demand to changes in own rates and opportunity costs. In particular, the own rate has been proxied by the interest rate on 90-day fixed-term deposits at chartered banks and the 90-day commercial paper rate is used as the competing rate of return in the computation of the opportunity cost. Ideally, for an aggregate, the own rate should be a deposit-weighted average of the own rates on deposits that comprise the aggregate and the opportunity cost should take into account rates on deposits outside the aggregate being modelled.

Section 3 examines the long-run demand for M2 and M2+ using quarterly data and recent advances in the field of applied econometrics - in particular, the intersection between cointegration and error-correction models - that permit more sophisticated examinations of the relationship between the demand for money and its determinants. This approach takes into account the nonstationarity of the money-demand variables. In particular, the concept of cointegration is designed to deal explicitly with the analysis of the relationship between nonstationary time series, while the error-correction model is designed to capture partial adjustment of one variable to another to achieve a final long-run equilibrium. Therefore, the appropriate use of cointegration and error-correction systems deals explicitly with the nonstationarity of the money-demand variables and with the dynamics of the money-demand process. The overall conclusion is (as expected) that money and the set of explanatory variables considered are not dependently related over time. This implies that velocity (based on M2 and M2+) is a nonstationary quantity and that M2 and M2+ would not be good policy targets.

Section 4 takes a disaggregated approach to modelling the demand for M2 using quarterly data and an autoregressive distributed-lag approach. Although the demand for currency is treated separately owing to perceived idiosyncrasies in its demand, the aggregation scheme reflects what are perceived (by the authors) to be close substitutes. For example, by grouping deposits together it is implicitly assumed that their prices (own rates) track each other fairly closely and respond similarly to market rates. Additionally, the separation of non-personal-sector deposits from personal-sector deposits reflects the assumption that non-personal-sector deposit rates exhibit different behavioural properties than personal-sector rates. Ideally, one should examine, for example, the correlations between the GDP velocities of the components of M2 and the treasury bill rate before constructing M2 subaggregates. Such correlations would also provide some information regarding the deposit flows within M2, as well as the adjustment of M2 deposit rates to market rates.

Although the disaggregated approach to the demand for M2 is potentially interesting, the paper fails to utilize this approach constructively. For example, the information from the disaggregated models concerning the effects of scale variables hasn't been applied to the aggregate M2 model. Moreover, the disaggregated approach is appropriate for modelling substitution effects among the components of M2 and, as a result, is useful in confronting the shifts of deposits within M2 caused by financial innovation and market rate changes. Although currency and demand deposits suffer from the lack of an explicit own rate and implicit rates of return are difficult to measure, the own rates of the subaggregates can be constructed (for example, as deposit-weighted averages of the own rates on deposits that comprise the subaggregates) and included in the disaggregated models to examine the potential substitutability across subaggregates.

In conclusion, I think that the point of the research in this paper has basically been to see if the variations in M2 and M2+ could be explained by two variables - a scale variable and opportunity costs. In general, the long-run demand for money would not be affected by the choice of the scale variable since, in the long run, the potential scale variables would be expected to move together. Similarly, the long-run demand for money would be insensitive to changes in interest rates since, over the long term, deposit rates adjust one-to-one to a change in market rates, leaving opportunity costs unchanged.

The inability to establish a long-run money-demand function may be due to what is broadly termed "misspecification." For example, M2 and M2+ may not be the best proxies for the underlying theoretical concepts they purport to represent. A second example of misspecification is the failure to include the right explanatory variables. For example, Milton Friedman (1988)[1] in exploring the role of the deflated stock price as a variable in the demand-for-money function, suggests that the real quantity of money demanded relative to income is negatively related to the contemporaneous real stock price, reflecting a substitution effect, and positively related to past real stock prices, reflecting a wealth effect. Friedman also argues that the wealth effect appears stronger and is better supported by the data than the substitution effect. All these possibilities could be explored by expanding the money-demand function to include the deflated price of equities. In fact, this is exactly what the disaggregated approach to the demand for M2 seems to suggest when used constructively.

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[1] Milton Friedman, "Money and the Stock Market," *Journal of Political Economy* 96 (April 1988): 221-245.

With regard to the short-run demand for money, whether it is modelled using a partial-adjustment specification, a distributed lag in the levels (or in the first differences) or an error-correction specification, depends on the purpose of the analysis. It seems, however, that the error-correction specification is more appropriate basically because it enables one to impose restrictions to guarantee that the short- and long-run money-demand functions are consistent. For example, one can distinguish the variables entering the short-run and long-run demand functions and impose suitable theoretical restrictions on the long-run function while maintaining flexibility in the short-run specification.

As was argued earlier, the long-run demand for money would not be sensitive to the choice of the scale variables and to changes in interest rates. The short-run demand for money, however, would definitely be sensitive to the choice of the scale variable. Perhaps using consumption instead of GDP may be the more appropriate approach since changes in some components of GDP may not require significant increases in money balances in the short run. Similarly, the short-run demand for money would be very sensitive to changes in opportunity costs - a fundamental consideration in the conduct of monetary policy. To this end, the spreads between market rates and deposit rates should be carefully considered as well as the speed of adjustment of deposit rates to market rates.

General Discussion

Gregor Smith opened the discussion of the paper by Caramazza, Hostland and McPhail (henceforth, CHM) by asking what it means to talk about adjustment speeds in the absence of a cointegrating (long-run) relationship between the variables. Kim McPhail noted that the difference between growth-rate and level specifications is in the disturbance to money demand. Thus, in the absence of cointegration, one can still talk about the short-run versus the long-run effects of a change in the level of one of the modelled determinants of money demand.

Paul Boothe noted that CHM consider three alternative money-demand models: the partial-adjustment model, the growth-rate model with Almon lags, and the error-correction model, and that these alternative specifications impose different restrictions on the dynamics. He wondered if it would be possible to test these alternatives as restrictions on a general, unrestricted model and determine, using traditional F-type tests, whether or not the restrictions are accepted by the data. Kim McPhail pointed out that that was basically what was done for the growth-rate specifications and for the error-correction and autoregressive distributed-lag specifications separately. However, the choice between a first-difference (of logarithms) or level equation could not be based on a standard F-test but on Augmented Dickey-Fuller and Phillips-Perron tests. Once that choice was made, standard F-type tests were used to test down the alternative models.

Charles Adams asked whether CHM allowed for drift in their error-correction models and whether they allowed for a break in trend. Doug Hostland remarked that with respect to allowing for drift in the error-correction models, one can look at the time trend in the cointegrating vector in two ways. First, one could think of it as just a method of detrending all the variables in the money-demand equation. Second, one could postulate that velocity is a stochastic process that may itself have a trend that proxies for financial innovations. Empirically, the two cases cannot be distinguished. Doug Hostland noted further that he was not aware of any test that involved cross-equation restrictions between short-run dynamics and long-run properties of the equation that involve the inclusion of a time trend.

Regarding the possible break in trend, Doug Hostland explained that previous work, using growth-rate models of money demand, had found evidence of a permanent downward structural shift in the level of money demand (the so-called consolidation shift) that had occurred gradually over a period of eight quarters. However, when that break was included in the cointegrating regression, it had a sign opposite to that expected, unlike the findings of Ambler and Paquet. David Longworth added that CHM did not test for shifts in the underlying time trends. In other words, they allowed only for level shifts.

Jon Cockerline found the consolidation hypothesis perplexing, and noted that there seemed to be two competing hypotheses in the paper. First, there is the suggestion that, following the 1982 recession, the private sector retrenched, selling off assets and paying down debts. But in the latter part of the paper, in the examination of personal-sector M2, the earnings-price ratio enters the equation with a very significant negative sign, suggesting that individuals were moving out of the stock market and into M2.

Kim McPhail pointed out that the authors wanted to test not only for substitutability among interest-earning assets, but also for substitutability between term deposits and the stock market, which is the reason the earnings-price ratio was included in the personal-sector M2 equation. However, it happened that the consolidation period coincided with a large change in the earnings-price ratio. By including the earnings-price ratio, the income elasticity is raised, thus allowing income to pick up more of the reduction in M2 associated with the recession.

Pierre Duguay expressed surprise that there had not been more discussion of the asymmetric effect of CSBs on M2 (that is, the finding that CSBs have a strong effect on M2 during the CSB sales period, but not during the redemption period) found in the aggregate first-difference equation, but not found in the disaggregated model. He said he would have thought that the hypothesis that at certain times of the year the substitution is between CSBs and money, while at others, it is between CSBs and treasury bills, would not be very convincing.

Jon Cockerline added that he was puzzled by the substitutability between CSBs and treasury bills as an explanation of the asymmetric CSB effect, since the M2 equation is estimated to 1987, whereas large retail sales of treasury bills only began in the mid-1980s.

Charles Freedman remarked that the asymmetric CSB effect may not be that puzzling. Different types of individuals buy CSBs. One would think that those who encash them quickly in response to changes in yields on alternative instruments are not "average" investors, but more sophisticated buyers who use securities dealers. In recent years, the introduction of high-return deposits may have altered previously established relationships, but it would still seem to be the case that those who encash their CSBs in the very early part of the year are the more marginal buyers - that is, those who buy CSBs because the interest rates are attractive. Then, if the rates become less competitive, they are prepared to encash them and invest in treasury bills or some other asset. The average buyer of CSBs, however, holds them longer. Such types of behaviour are difficult to distinguish empirically; it is a lot to ask of the data, especially in light of the fact that in the last few years, with the introduction of investor-type accounts, behaviour may have changed - in which case, one would expect a more symmetrical CSB effect in recent years.

Freedman also noted that the distinction between error-correction models and growth-rate models was not merely technical, for important policy issues were involved. If one believes the growth-rate model, then a shock to money has permanent effects. If the shock is truly random, then the monetary authorities ought not to respond by trying to get money back to its earlier path. On the other hand, if one believes the error-correction model, then one is saying there is a long-run path and the monetary authorities should keep to that path. Base drift makes sense in one case and not in the other.

Kim McPhail wondered how much it really matters for policy whether one uses a growth-rate model or an error-correction model if the distinction is between a unit root and a near-unit root. Freedman agreed, but noted that it could make a difference for the interpretation of movements in the monetary aggregates. If all, or a very high portion of the movements are associated with the error term, then the usefulness of the monetary aggregates in the short to medium run is much reduced.

Peter Howitt added that the implications for policy depend not simply on whether the shocks are permanent or transitory, but also on how one interprets them. The error term could be interpreted as a pure change in the portfolio preferences of depositors unrelated to the lending activities of banks, or it could reflect, for example, a change in the willingness of financial intermediaries to extend credit. Specifically, if one interprets developments such as those that occurred in 1983 as agents wanting to hold less M2 and more of other things, then the appropriate policy response would be to accommodate the shock. However, if the shock indicates a reduced willingness of financial intermediaries to lend, it will show up not only in a shrinking of these assets, but also of their liabilities, and thus in M2 and the broader monetary aggregates. In this case, the implications for policy are different, even though the effect on velocity may be permanent.

Following up on Howitt's comment, Freedman noted that he thinks of M2 as being mainly demand-determined, whereas Howitt (and Laidler) would say that there is also a supply-side element to the determination of M2. He argued that if the own rate of interest on M2 deposits could be correctly measured, then M2 would be totally demand-determined. Freedman considered that the supply-side effect was much more convincing for M3 in that if lending drops significantly, financial institutions will adjust their balance sheets by adjusting the deposits that are included in M3. However, if bank loans are reduced, either because of a decision to reduce the amount of lending or because of a reduced demand for loans, the way a bank adjusts is to change its own rates on deposits included in M2 relative to market rates. Although the differences in interpretation may not have important implications for the short run, they do suggest different explanations of episodes such as the 1982-84 period.

COINTEGRATION AND THE DEMAND FOR M2 AND M2+ IN CANADA

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by Steve Ambler and Alain Paquet*

Introduction

Given the well-known instability of money-demand equations using M1 and other narrow measures of the money stock, the Bank of Canada has begun investigating the stability of relationships involving wider measures of the money stock. The Bank's interest in this area of research has been spurred by internal studies on indicator models that indicate high correlations between changes in M2 and M2+ on the one hand, and inflation and economic activity on the other.[1] In particular, of all the monetary aggregates, researchers at the Bank have found M2+ to be the most closely correlated with the growth in total real spending. This has led the Bank to monitor closely the evolution of M2 and M2+ and to intensify its search for stable demand functions for these aggregates. In this paper, we build on previous work conducted at the Bank of Canada[2] on the demand for M2 and M2+.

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[1] See Crawford (1990, in this volume) and Muller (1989) for a survey of some of these results.

[2] See Caramazza (1989), McPhail and Caramazza (1990) and Caramazza, Hostland and Poloz (1990).

* *We would like to thank the Bank of Canada for providing data and comments on a draft proposal of this paper as well as participants at the planning meeting at the Bank in December 1989 and at the Monetary Seminar itself, especially Jean-Marie Dufour and Steve Poloz.*

Our strategy, following the literature on cointegration in economic time series by Engle and Granger (1987) and others, consists of two stages. In the first, we identify a long-run demand-for-money function by looking for cointegration relationships among the levels of variables that are found in standard demand-for-money equations. In the second stage, we model the dynamics of money demand as an error-correction mechanism, with both deviations from long-run money demand and differentials between own rates and competing rates of return as error-correction terms.

By concentrating on long-run relationships in the first part of the paper, we can temporarily set aside worries about simultaneity.[3] As shown by Engle and Granger (1987) and Stock (1987), simultaneity problems are irrelevant (at least asymptotically) for the estimation of cointegration relationships.

Our principal findings can be summarized as follows. The velocities of both M2 and M2+ appear to contain unit roots. However, when a once-and-for-all change in deterministic time trend is taken into account (with the break occurring after January 1983), both measures of velocity are shown to be stationary around a breaking deterministic time trend. We are unable to find any long-run money-demand equation that includes a measure of the opportunity cost of holding money and yields residuals that are significantly more stationary than the velocity measures. This result is consistent with our finding that all the short-term interest rates in our data set are cointegrated. Since most of the components of M2 and M2+ are interest-bearing assets, it seems reasonable that a change in short-term rates that leaves unchanged the spread between the own rate of return and rates of return on competing assets would not affect the level of money demand in the long run.[4]

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[3] The papers written at the Bank of Canada by Caramazza, Hostland and Poloz (1990) and by McPhail and Caramazza (1990) contain clear discussions of the simultaneity issue. See also Cooley and Leroy (1981) and Poloz (1980).

The data are consistent with the hypothesis of a unitary income elasticity of money demand in the long run. When we estimate the coefficients on GDP in the velocity equations, the residuals are not significantly more stationary than when a unitary coefficient is imposed. The error-correction models of money-demand dynamics yield estimates that are strongly in agreement with economic intuition. Lagged deviations of velocity from its long-run (breaking) trend have a great deal of explanatory power in both the M2 and M2+ equations. Lagged short-term interest rate differentials also have explanatory power in the M2+ equation. An increase in the own rate of return relative to competing rates of return leads to a significant increase in money demand with a one-period lag. If the coefficient on our velocity error-correction term is interpreted as a speed of adjustment towards long-run equilibrium, we find an adjustment speed similar to that of a previous Bank of Canada study using quarterly data.[5]

In the following section, some of the basic time-series properties of the individual variables in our data set are investigated. Next, we describe the methodology used in the attempt to uncover a stable long-run money-demand relationship and present the results of a series of cointegrating regressions, as well as the results of tests of cointegration of short-term and long-term interest rates. These test results form the basis of the error-correction models of money demand specified in the subsequent section. We then report our findings for general dynamic money-demand equations, and describe the methodology used to "test down" to more parsimonious representations of the two relationships. Given our final specifications, we present the results of some simulation exercises as well as some out-of-sample forecasts performed with equations estimated over a portion of the entire sample. We then sum up with our concluding remarks.

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[4] It is possible that a change in short-term rates would lead to a shift in demand among the various components of M2 or M2+. We do not explore this possibility in our paper.

[5] See Caramazza, Hostland and Poloz (1990).

1. Time-Series Properties of the Individual Series

Our data set, provided by the Bank of Canada, contains monthly observations on a set of Canadian and U.S. time series, including Canadian M2 and M2+, Canadian GNP and a large number of short- and long-term interest rates. The original sources of these data are described in detail in an appendix. In previous studies, Bank of Canada researchers (see McPhail and Caramazza, 1990) used the GNP deflator as their basic price variable. Since the GNP deflator is available on a quarterly basis only, this involves generating a monthly series by interpolation. We preferred to use the consumer price index, which is available on a monthly basis over the entire sample period (1969:01-1989:11). The dynamic money-demand equations we estimate are based on a sample that starts in the early 1970s because of the large number of lags on the variables included in these equations.

First, we performed unit root tests on all the individual series in our data set. Two types of tests were run on each series. The first used the methodology developed by Perron and Phillips (as described in Perron, 1988), which involves a non-parametric correction for serial correlation in the residuals of standard Dickey-Fuller (1979) regressions. Results from the unit root tests on the levels of the series are shown in Table 1. The null hypothesis of a unit root could be rejected for none of the series in the data set. The Phillips-Perron test uses a lag-truncation parameter to compute the otherwise non-parametric correction. The choice of this truncation parameter

Table 1
Unit Root Tests on Individual Time Series

Variable	$Z(t_\alpha)$	ADF	Variable	$Z(t_\alpha)$	ADF
M2	-0.678	-1.613	**ΔM2**	-14.575	-3.476
M2+	-0.297	-1.187	**ΔM2+**	-12.864	-3.347
P	-0.535	-2.656	**ΔP**	-13.378	-1.728
Y	-2.120	-2.284	**ΔY**	-18.122	-4.757
R90	-2.422	-2.500	**ΔR90**	-10.629	-4.777
B90	-2.016	-1.572	**ΔB90**	-6.982	-3.949
T90	-2.115	-1.556	**ΔT90**	-6.493	-3.973
CSB	-3.201	-3.590	**ΔCSB**	-17.281	-2.962
RUS	-2.529	-2.080	**ΔRUS**	-12.946	-4.556
RB5	-1.895	-1.622	**ΔRB5**	-7.816	-3.343
RM5	-1.197	-1.051	**ΔRM5**	-7.869	-2.714
VM2	-2.050	-2.299	**ΔVM2**	-4.945	-5.617
VM2+	-1.566	-1.882	**ΔVM2+**	-4.462	-4.761

Critical value at 5 per cent, approximately -3.43, -3.99 at 1 per cent (Fuller, 1976, p. 373)

Note: Variables are defined in the Data Appendix except for: VM2, the velocity of M2, and VM2+, the velocity of M2+. Calculated values of $Z(t_\alpha)$ are for the Phillips-Perron test with a lag-truncation parameter ℓ equal to 12 (see Perron, 1988). Calculated values of ADF are for an Augmented Dickey-Fuller test with 12 lags of the differenced variable included in the regression.

is arbitrary.[6] The results reported in Table 1 are for a truncation parameter equal to 12, but the discovery of a unit root in all the series did not depend on this choice. The second test was the Augmented Dickey-Fuller test, which involves adding lags of the first difference of the dependent variable of the standard Dickey-Fuller regression in order to correct for serial correlation. Several different lag lengths were tried, and Table 1 shows the results from a set of regressions with 12 lags. The results confirm the finding of a unit root in the levels of all the series except Canada Savings Bonds, for which it is possible to reject the null hypothesis of a unit root at a significance level of 5 per cent.

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[6] Note, however, that in order for the tests to be consistent, the value of the truncation parameter must be allowed to increase in a way that is systematically related to the size of the sample.

Since many of our results turn out to hinge on the stationarity of velocity around a breaking trend, it was important to establish that the inability to reject the null hypothesis of a unit root for the individual time series was not due to structural breaks that would make trend-stationary series appear to contain unit roots. In order to detect possible structural breaks in the univariate stochastic processes of the individual series, we followed a method used previously by Paquet (1989) which involves calculating recursive autocorrelation functions of the series. Structural breaks in the series should induce spikes in the autocorrelation functions when post-break data are added. Using recursive autocorrelations does not constitute a formal test of the existence of structural breaks, but can indicate potential breaks in a series that can then be subjected to more formal testing. We found no such evidence of structural breaks for the individual series in our data set.

We then proceeded to test the first differences of our series for unit roots. Using the Phillips-Perron test, the null hypothesis of a unit root could be rejected for all of the series at conventional significance levels in favour of the alternative hypothesis of stationarity around a deterministic time trend. Results are shown in Table 1. These results for monthly data are consistent with those reported in Ambler (1989) using a slightly different data set. The results of Augmented Dickey-Fuller tests on the first differences of the series are also shown in Table 1. These are broadly compatible with the results of the Phillips-Perron tests, but M2+ and RB5 are now at the borderline of the rejection region at a significance level of 5 per cent, and it is no longer possible to reject the null hypothesis of a unit root in the case of RM5, P and CSB. The results are paradoxical in the case of the Canada Savings Bond variable, which is stationary in levels according to the Augmented Dickey-Fuller test.

These results suggest that dynamic money-demand equations should be estimated with variables measured in first differences, as in McPhail and Caramazza (1990). However, if there are significant long-run relationships among the levels of variables, not taking these relationships into account would constitute a specification error. Therefore, our next move was to look for evidence of long-run relationships in the data.

2. Long-Run Relationships

The first step in searching for long-run money-demand relationships was to test the null hypothesis of a unit root in the velocities of M2 and M2+. The results (using the Phillips-Perron methodology) are shown in Table 1. The unit root hypothesis cannot be rejected at conventional levels of significance. Figure 1 illustrates the behaviour of the velocities of M2 and M2+ over the sample. (See appendix for figures.) It is clear from the figure that both measures of velocity change sharply during 1983.

We then tested to see if the deviations of velocity from a breaking trend contained a unit root. The method involved experimenting with the selection of a date for the break in trend. Clearly, this procedure implies a form of data mining. In a related context, Christiano (1988) criticizes Perron (1989) for using overly liberal critical values to reject the unit root hypothesis for U.S. GNP when allowing for breaks resulting from the Great Depression and the first OPEC oil price shock. Perron (1989) notes that the results of his tests assume the 1929 crash and the 1973 oil price shock are exogenous events that are part of the researcher's information set before the data are evaluated.

Since we were unable to identify any well-defined historical event that could explain a break in velocity in 1983 (even after examining the data), it was important to take this into account in deriving correct critical values for our tests. Fortunately, a recent paper by Perron (1990) derives correct significance levels for unit root tests when one break in the trend is allowed for. The procedure involves conducting Augmented Dickey-Fuller tests for all possible break points in the sample and for a range of lag lengths in the Augmented Dickey-Fuller regressions. Perron uses Monte Carlo simulation techniques to derive the critical value when the breakpoint and lag length are chosen in order to maximize the absolute value of the t-statistic.

The results of applying the Perron procedure to M2 and M2+ velocity are illustrated in Figures 2 and 3, respectively (see appendix). We allowed for a once-and-for-all shift in the level of the deterministic time trend. The figures show the absolute values of the t-statistics to test the unit root hypothesis as a function of the breakpoint and the number of lags of the endogenous variable included in the regression. We can reject the null hypothesis of a unit root using the critical values calculated by Perron. Not only does the most significant breakpoint occur after January 1983, but the figures indicate that the values of the t-statistics decrease quite rapidly on either side of this breakpoint. We believe that the visual evidence provided by the figures reinforces the strength of the results of the formal tests of the hypothesis.

We next replaced the unit coefficients in our velocity measures with coefficients obtained by regressing real money balances on GDP as a rough test of the hypothesis that the data are compatible with a long-run income

Table 2.1
Estimates of Long-Run Income Elasticity of Money Demand

Dependent variable	M2-P	M2+-P
Intercept	-1.474 (-2.29)	-5.189 (-7.18)
Dummy	-0.123 (-20.86)	-0.147 (-21.44)
Time trend	0.002 (13.15)	0.002 (10.85)
Y	0.648 (12.29)	0.982 (16.57)

Note: Dummy is a variable that takes the value 0 before January 1983 and 1 thereafter. T-statistics are in parentheses. The sample for both equations runs from 1969:01 to 1989:09.

elasticity of money demand equal to one.[7] The estimates are summarized in Table 2.1. Table 2.2 reports unit root tests on the residuals from the regressions in Table 2.1. The point estimates of the coefficients on GDP in the regressions are several standard deviations away from one, but inference is complicated by the fact that distributions are non-standard under the hypothesis that GDP contains a unit root. In Table 2.2, the t-statistics of unit root tests on the residuals of these equations are compared with those of unit root tests on the deviations of velocity from a breaking trend with a unit coefficient imposed. Allowing for an estimated coefficient on GDP causes a negligible change in the t-statistics in the case of M2+, and leads to a slight increase in their value in the case of M2, depending on the type of test used.

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[7] We maintain the hypothesis of long-run price homogeneity throughout.

Following Engle and Yoo (1987), we noted that allowing one more free parameter in the cointegrating regression biases the unit root tests towards rejection unless critical levels are adjusted to reflect the extra free parameter in the cointegrating regression. Because we include a breaking time trend in the regressions, we cannot use the Monte Carlo results of Engle and Yoo to conduct a formal hypothesis test, but we take the results as being roughly compatible with the hypothesis of a long-run unitary income elasticity.

Table 2.2
Unit Root Tests on Residuals of Cointegrating Equations

Equation	$Z(t_\alpha)$	ADF(0)	ADF(12)
M2 velocity deviation from breaking trend	-3.73	-3.47	-3.46
M2+ velocity deviation from breaking trend	-3.83	-3.44	-3.67
M2 velocity with estimated coefficient on Y	-4.01	-3.78	-3.82
M2+ velocity with estimated coefficient on Y	-3.83	-3.45	-3.67
M2 demand 1	-3.67	-4.30	-3.26
M2+ demand 1	-3.65	-3.86	-3.38
M2 demand 2	-4.40	-4.78	-4.04
M2+ demand 2	-4.49	-4.24	-4.18

Note: The "demand 1" equations add R90 and B90 as explanatory variables to the reported regression. The "demand 2" equations add R90, B90, R90-B90, and CSB to the equations following McPhail and Caramazza (1990) and model the structural break as they do (see text for details). Calculated values of $Z(t_\alpha)$ are for the Phillips-Perron test with a lag-truncation parameter ℓ equal to 12 (see Perron, 1988). Calculated values of ADF (0) are for an Augmented Dickey-Fuller test with no lags of the differenced variable included in the regression. Calculated values of ADF (12) are for an Augmented Dickey-Fuller test with 12 lags of the differenced variable included in the regression.

These results justified our choice of detrended velocity as the basis for our error-correction specifications of money-demand dynamics, but we wished to explore the marginal contribution of other variables, notably the interest rate, to the long-run money-demand relationship. In Table 2.2 we report the results of a test of the unit root hypothesis on the residuals of cointegrating regressions that include as explanatory variables the 90-day corporate paper rate and the rate on 90-day fixed-term deposits at chartered banks. For all tests except the Augmented Dickey-Fuller test with 12 lags, the absolute value of the t-statistic is smaller for both the M2 and M2+ residuals compared with the t-statistics from unit root tests on the deviations of M2 and M2+ velocities from a breaking trend. Given the added sampling error that is involved, we interpret this result to be compatible with the hypothesis that interest rates add no significant explanatory power to the equation.

These findings are not surprising given the results of further tests of cointegration relationships among interest rates. We found that short-run interest rates were mutually cointegrated while short and long rates were not. The results of cointegration tests on interest rates are presented in Table 3. For short-term interest rates, we were able to reject the null hypothesis of a unit root for pairs of interest rates in all cases but the 90-day corporate paper rate and the 90-day bank term deposit rate, on the basis of the Phillips-Perron test. The tests were conducted using straight interest rate differentials, which means that we imposed a unit coefficient on the cointegrating vectors. The acceptance of the unit root hypothesis in the case of the 90-day corporate paper rate and the 90-day bank term deposit rate is puzzling, but we note that cointegration of these two rates is implied by the finding that both of these rates are cointegrated with the U.S. 90-day commercial paper rate and, further, that they appear to be cointegrated with the 90-day term deposit rate at trust and mortgage loan companies.

Table 3
Unit Root Tests on Interest Rate Differentials

Variable	$Z(t_{\alpha})$	ADF(0)	ADF(12)
B90-R90	-3.151	-3.226	-2.810
B90-T90	-3.958	-3.888	-4.161
B90-RB5	-2.587	-2.244	-2.482
B90-RM5	-2.253	-1.392	-2.233
B90-RUS	-4.468	-4.505	-2.996
R90-T90	-4.489	-4.340	-2.254
R90-RB5	-2.428	-2.346	-2.266
R90-RM5	-1.720	-1.067	-1.854
R90-RUS	-4.830	-4.828	-2.839
T90-RB5	-2.899	-2.666	-2.928
T90-RM5	-2.436	-1.712	-2.643
T90-RUS	-4.745	-4.794	-2.740
RB5-RM5	-2.465	-2.088	-2.917
RB5-RUS	-3.951	-4.029	-2.739
RM5-RUS	-3.738	-3.689	-3.190

Critical value at 5 per cent approximately -3.43, -3.99 at 1 per cent (Fuller, 1976, p. 373)

Note: Variables are defined in the Data Appendix. See the note to Table 2.2 for definitions of $Z(t_{\alpha})$, ADF(0) and ADF(12).

These results are based on the Phillips-Perron test shown in the first column of the table. They are corroborated by Augmented Dickey-Fuller tests when only a few lags of the dependent variable are included; the second column of Table 3 shows results for the case with no lags. With a larger number of lags (the third column of the table shows results for the case of 12 lags), the evidence for cointegration is weaker. This may result from a loss of power due to the estimation of a greater number of nuisance parameters. Table 3 also presents results concerning the cointegration of short and long rates. In general, it is not possible to reject the null hypothesis that long and short rates are not cointegrated. One puzzling feature of the results is that Canadian long- and short-term rates appear not to be cointegrated, while Canadian long-term rates appear to be cointegrated with the U.S. 90-day corporate paper rate (at 5 per cent but not at 1 per cent). These results are broadly compatible with those presented by Boothe (1991) using a different data set.

Given the cointegration of pairs of short-term interest rates, this means that the own rate of return on M2 and M2+ (which we take, in accordance with Bank of Canada studies, to be proxied by the 90-day term deposit rate at chartered banks) moves in lockstep in the long run with rates of return on competing assets. Since most of the components of M2 and M2+ bear interest, the real opportunity cost of holding money is constant in the long run. It should not, therefore, be surprising that adding opportunity cost measures to the variables that are potentially cointegrated does not lead to a significantly better long-run money-demand relationship.

Finally, we experimented with alternative methods of imposing a break in the long-run behaviour of velocity. McPhail and Caramazza (1990), in their study of the demand for M2 and M2+, account for structural change in the 1980s using a dummy variable that allows the rate of growth of demand for M2 and M2+ to increase discretely between July 1982 and November 1984. We estimated an equation in levels corresponding to their specification in first differences, with real balances regressed on a constant, GDP, the 90-day corporate paper rate, the 90-day bank term deposit rate, the difference between these two rates, and the real value of outstanding Canada Savings Bonds as regressors. Our breaking time trend was replaced by a dummy variable that increased in linear fashion from July 1982 to November 1984 and remained at its November 1984 level thereafter, which effectively allows for an increase in the growth rate of money demand during this period.

Results from a test of the unit root hypothesis on the residuals of these cointegrating equations are reported in Table 2.2. For both the M2 and the M2+ equations, the absolute values of the t-statistics increase substantially when compared with tests on the deviations of velocity from a breaking trend. Given the added sampling error involved with equations with a large number of estimated parameters, we concluded that the data are compatible with our methodology of modelling the long-run behaviour of the money stock using a breaking linear trend in velocity. However, in future work, it may be worthwhile to pursue more elaborate ways of modelling the 1983 break in velocity.

We conclude this section with a summary of the principal results. The data seem to be compatible with the hypothesis that velocity (of both M2 and M2+) is stationary around a deterministic time trend when a once-and-for-all change in the mean of the time trend is allowed after January 1983. The data are also compatible with the hypothesis of a unitary long-run income elasticity of money demand. Finally, adding measures of the opportunity cost of holding money does not significantly improve the fit of the long-run relationship. Some of the results of this section are based on test statistics whose true critical values are not known. We take the true test of the validity of these results to be the significance of the error-correction term coefficients in the dynamic regressions of the following section. In light of these results, we use the lagged deviations of velocity from a breaking time trend as an error-correction term in each of the dynamic money-demand equations we estimate in the next section. We also use lagged differentials between different short-term interest rates as error-correction terms to capture the dynamic effects of changes in the difference between own rates of return and rates of return on competing assets.

3. Error-Correction Equations

Recent advances in time-series econometrics offer a useful strategy for modelling the short-run dynamics of the adjustment of money demand without neglecting a consistent link with its long-run behaviour. Nominal rather than real balances are used since it seems unrealistic to assume that nominal balances adjust instantaneously to changes in the price level, while real balances adjust slowly to changes in the other determinants of money demand. Accordingly, we began by estimating a "general" specification, modelling the first difference of the logarithm of M2 (and M2+) which depended upon:

- an intercept;
- twelve lags of the first difference of the corresponding monetary aggregate (in logs);
- the contemporaneous value as well as 12 lags of the first difference of each of: the log of prices, the log of real output, the first difference of the interest rate on 90-day corporate paper, and of the first difference of the interest rate on 90-day fixed-term deposits in chartered banks;
- the contemporaneous value and one lag of the first difference of the real outstanding stock of Canada Savings Bonds;
- dummy variables included to capture the effects of postal strikes in Canada on the behaviour of the monetary aggregate, in April and May 1974, in October, November and December 1975, in November 1978, in July 1981 and in August 1981;
- intercept dummy variables added to capture monthly seasonal effects;
- an error-correction term representing the first lag of the differential between the interest rates on 90-day fixed-term deposits and 90-day prime corporate paper, B90(-1) - R90(-1);
- an error-correction term representing the first lag of the differential between the interest rates on 90-day fixed-term deposits at chartered banks and on corresponding assets at trust and mortgage loan companies, B90(-1) - T90(-1);

- an error-correction term linking the short-run dynamics to the long-run equilibrium relationship, expressed as the first lag of the deviation of the inverse of velocity from a breaking time trend after January 1983.

In order to find a more parsimonious representation of the dynamic relationships estimated for M2 and M2+ over both the 1970:02-1988:12 and 1970:02-1989:09 samples, we identified all of the parameters whose t-statistics were below one in absolute value and tested whether these coefficients were jointly equal to zero. Because we had included in the general model many lags of variables that were likely to be highly correlated, this procedure was judged to be more appropriate and less likely to lead us to drop important and significant regressors. Appendix Tables A:1 and A:2 show the OLS estimates of the parsimonious representation for M2 and M2+, respectively.[8] The F-statistics for testing the null hypotheses of the insignificance of 43 regressors in the M2 equation and 42 regressors in the M2+ equation were low enough that they could not be rejected at a 6 per cent significance level and a 94 per cent significance level, respectively. Further eliminations of extraneous regressors, although possible, were not attempted.

Underlying the technique used in this paper is the assumption that the model under study respects certain conventions that make the OLS estimation procedure valid, with respect to the specification, the behaviour of the residuals, the stability of the model, and so forth. It thus appears appropriate to test for possible departures from this set of conventions, since such problems can yield seriously spurious inferences and thus invalidate our results. Hence, several diagnostic tests for model inadequacy were performed on our chosen specifications for M2 and M2+. These were: a Lagrange multiplier (LM) test for residual serial correlation, χ^2_{sc}; a RESET test for the functional form using the square, the cube and the fourth power of the fitted value, χ^2_{ff}; the Jarque-Bera test of normality of the residuals, χ^2_n; an LM test for heteroskedasticity based upon the regression of squared residuals on squared fitted values, χ^2_h; and an ARCH test for autoregressive conditional heteroskedasticity, χ^2_{ARCH}. Finally, a Chow test for stability of the coefficients was also performed.

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[8] Estimates for the general specifications are available upon request.

The results of these tests are provided in Appendix Tables A:1 and A:2 along with the estimation results. Except for the normality test, all the other diagnostic tests do not suggest any significant problems with the specification of the error-correction models, with serial correlation or with heteroskedasticity. As is often the case in papers where the Jarque-Bera test is reported, there is some evidence that the residuals from our specifications do not behave according to a normal distribution.[9] However, for the M2+ equation over the 1970:02-1989:09 sample, the calculated value of the $\chi^2_n(2)$ statistic for testing normality of the residuals does not allow rejection at 1 per cent. We take comfort nevertheless in the fact that the nominal size of the other misspecification tests is fairly small.

A Chow test for parameter constancy over the whole sample was implemented by splitting the sample in January 1982. Results of this test both for the M2 and the M2+ equations do not suggest instability of our chosen specifications.[10]

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[9] An examination of the plots of the residuals does not suggest that this rejection can be accounted for by the presence of many significant outliers.

[10] Because of the dummy variables included to capture the effects of postal strikes in the subsample prior to January 1982, the Chow test applied here differs slightly from the usual test. Let RSS_0, RSS_1 and RSS_2 be the sum of squared residuals, respectively, for the whole sample, the first subsample and the second subsample. Also, k_i and n_i are the number of regressors and the number of observations for the subsample i, where i = 1, 2. Accordingly, the statistic used to perform the Chow test is:

$$F = ((RSS_0 - RSS_1 - RSS_2)/k_2)/((RSS_1 + RSS_2)/(n_1 + n_2 - k_1 - k_2))$$

since there are only k_2 regressors in common in both subsamples.

The error-correction terms IVM2(-1) and IVM2+(-1) (each defined as the lag of the deviation of the inverse of velocity from a breaking time trend), were significant and negative in their respective equations. Note that these variables ensure that money demand is homogeneous of degree one in prices and that there is a unitary income elasticity of money demand in the long run. This is in agreement with the results presented in the first part of our paper. Since the coefficients of these variables are negative, this means that if actual velocity is below its trend value (that is, the error-correction term is positive), nominal money demand will decrease, *ceteris paribus*.

The point estimates of the error-correction terms are about -0.05 and -0.03 for M2 and M2+, respectively. If this is interpreted as an indicator of the speed of adjustment of money demand towards its long-run equilibrium, it would mean that most of the dynamic adjustment takes place within 14 months for M2 and within 23 months for M2+. However, this must be taken as a rough indicator only. The short-run dynamics built into our specifications are more complex, since lagged values of the growth rate of the nominal money stock, the price level and real income also significantly affect the speed of adjustment. This may either increase or reduce the speed of adjustment of money demand towards its long-run value. The simulation exercises in the next section provide a complementary assessment of the length of this dynamic adjustment. Finally, the error-correction coefficient in the M2+ equation is similar to a value of just over 10 per cent per quarter estimated by Caramazza, Hostland and Poloz (1990) (Table 1).[11]

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[11] Inference related to the error-correction term is complicated by the fact that it incorporates a deterministic linear time trend. We attempted to re-estimate the model by nonlinear least-squares methods instead of Engle and Granger's two-step method as a test on the robustness of the results. Unfortunately, owing to the large number of parameters in the model, the algorithm used did not converge.

The error-correction term in the interest rate differential between the own interest rate of the monetary aggregate relative to the return on competing assets, as measured by the variable (B90(-1) - R90(-1)), is significant at the 17 per cent level in the M2 equation and at the 0 per cent level in the M2+ specification. This suggests a positive effect on money demand as would be predicted by theory. The lower significance level of this coefficient in the M2 equation may well be due to multicollinearity with the variable (B90(-1) - T90(-1)).[12]

This additional error-correction term, as expected, is positive and significant (at the 5 per cent level) in the M2 equation. Notwithstanding their respective levels of significance, it is interesting to note that the coefficient of the variable (B90(-1) - T90(-1)) is about four times larger than the coefficient of (B90(-1) - R90(-1)) in the M2 equation. Hence, if the return on similar assets offered by chartered banks is higher than that offered by trust and mortgage loan companies, the demand for M2 should increase. Finally, this term is not significant in the M2+ equation as the induced substitution between these comparable assets is already accounted for within M2+.[13]

The results also show very clearly that changes in the real value of outstanding Canada Savings Bonds are an important determinant of the dynamics of money demand. The original justification for the inclusion of

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[12] The correlation coefficient between (B90(-1) - R90(-1)) and (B90(-1) - T90(-1)) is equal to 0.68 and 0.71 for the 1970:02-1988:12 period and the 1970:02-1989:09 period, respectively.

[13] In other regressions not reported in this paper, we have also explored the possibility that there is some currency substitution with U.S. assets that would affect the dynamics of Canadian money demand. Under the hypothesis that the exchange rate behaves as a random walk, the opportunity cost of foreign transactions balances is measured simply by the nominal U.S. interest rate. Defining RUS as the U.S. interest rate on 90-day commercial paper, we found that the error-correction term (RUS(-1) - R90(-1)) was not significant. However, this does not mean that changes in RUS do not affect the dynamics. If U.S. and Canadian assets are highly substitutable, these dynamics are captured by the effects of changes in Canadian interest rates.

Canada Savings Bonds would seem to be as a proxy for wealth and thus as a scale variable for money demand. The highly significant negative impact of an increase in CSBs on money demand gives a strong empirical justification for including them but necessitates a different theoretical justification. We are inclined to agree with the interpretation offered in previous Bank studies, that an increase in the outstanding stock of CSBs constitutes an increase in the supply of an asset that competes for households' savings.[14]

Finally, the seasonal intercept dummy variables that are significant suggest that the growth rate of nominal money demand for M2 and M2+ is higher for the last two and the first two months of the year compared with other months.[15] Except for the last month of the 1975 postal strike and the 1981 strike, postal strikes have had a significant temporary positive effect on the growth of the monetary aggregates.

4. In-Sample Simulations and Out-of-Sample Forecasting Exercises

Based on the estimations for the ΔM2 and ΔM2+ equations over the 1970:02-1988:12 sample, we have transformed the models in levels and conducted both in-sample simulations and out-of-sample dynamic forecasts for the first nine observations of 1989.

Figures 4 to 9 (see appendix) illustrate the dynamics of the adjustment of money demand towards its long-run equilibrium value, following a permanent rise in the value of each corresponding variable. The price level, real GDP and the real outstanding stock of Canada Savings Bonds were subjected to an increase in value of 1 per cent. The interest rate variables were increased by 100 basis points.

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[14] See McPhail and Caramazza (1990) and Caramazza, Hostland and Poloz (1990).

[15] Note that most of the variables in our data set were seasonally adjusted at source (the CPI is the main exception to this rule). This suggests that there may be serious inadequacies in the procedures used by Statistics Canada for seasonal adjustment, and that further work should be undertaken to model money demand with unadjusted data.

Table 4 contains the long-run elasticities and semi-elasticities of money demand for M2 and M2+ that are consistent with the estimates of the error-correction models shown in Appendix Tables A:1 and A:2. As imposed by the specification of the error-correction mechanisms, the long-run income and price elasticities of money demand are equal to one. Also, an increase in the real stock of Canada Savings Bonds has only a temporary effect on money demand. The estimates of the semi-elasticities imply that an increase of 100 basis points in R90, which measures the opportunity cost of holding the monetary aggregate, reduces M2 and M2+ by 1.11 per cent and 3.79 per cent, respectively. In contrast, a similar change in B90, which measures the effect of the own interest rate, increases M2 by 5.28 per cent and M2+ by 3.79 per cent in the long run. In the case of M2, if T90 decreases by 100 basis points causing a gap between the returns on comparable assets at chartered banks and at trust and mortgage loan companies, the demand for M2 rises by 4.17 per cent in the long run.

Generally, it was found that the speed of adjustment of money demand towards its long-run value is fairly consistent with that suggested by the coefficient of the lag of the deviation of the inverse of velocity from a breaking time trend. Figures 4 to 9 show that a major proportion of the adjustment induced by shocks to the determinants of money demand is completed within two years both for M2 and M2+. Full adjustment takes longer. We also found that M2+ tends to adjust more slowly than M2.

About 90 per cent of the impact of a change in the price level on M2 is felt within the first 12 months. This compares with 16 months for M2+. A rise of 1 per cent in real GDP causes a 0.87 per cent increase in M2 after

Table 4
Long-Run Elasticities and Semi-Elasticities of Money Demand Consistent with the Estimates of the Error-Correction Models for M2 and M2+ (1970:02-1988:12)

Money-demand variable	M2	M2+
P*	1.00	1.00
Y*	1.00	1.00
CSB*	0.00	0.00
R90**	-1.11	-3.79
B90**	5.28	3.79
[B90 - T90]**	4.17	-

* Elasticity: Effect in per cent of a 1 per cent rise in the variable.
** Semi-elasticity: Effect in per cent of a 100-basis point rise in the variable.

20 months, and a similar effect after 11 months for M2+. However, M2+ later overshoots its long-run value increasing to 1.11 per cent before beginning to decrease towards 1 per cent. A 1 per cent increase in the real stock of CSBs reduces M2 by 0.09 per cent after 7 months and M2+ by about 0.1 per cent after 10 months. This effect is less than 0.01 per cent after 28 months for M2 and 44 months for M2+. Changes of 100 basis points in own and competing interest rates are followed by comparable lengths of adjustment. For instance, the demand for M2+ rises by 3 per cent 28 months after an increase in B90, while it is reduced by 3 per cent 28 months after a decrease in R90. The rest of the adjustment takes another 47 months.

Figures 10 and 11 illustrate how the specifications perform in out-of-sample forecasting of the level of M2 and M2+ in the first part of 1989. For purposes of comparison, these graphs show the actual values of M2 (and M2+), the predicted values from 1987:01 to 1988:12 (the part of the sample used for estimation), and the dynamic forecast from 1989:01 onwards. The root-mean-squared error of the forecast over the nine observations was 0.004690 and 0.005213 for M2 and M2+. This compares favourably with 0.003184 and 0.002332, which are the in-sample root-mean-squared errors of the predicted values of M2 and M2+. The specifications that we estimated seem therefore to have done a good job.

5. Conclusions

Insofar as the explanatory power and the forecasting properties of our money-demand equations depend on a gradual but systematic elimination of deviations of velocity from its long-run trend, the results may not be too encouraging to policy-makers at the Bank of Canada. Our results depend heavily on imposing a break in the long-run trend of velocity in 1983. We view this break as an exogenous event. Various hypotheses have been proposed to try to explain the sharp decrease in the demand for M2 and M2+ at the beginning of the 1980s, but these hypotheses are best thought of as conjectures that have little theoretical or empirical support.[16] This means that using money-demand equations to formulate policy depends on the stability of the post-1983 section of the deterministic linear trend in velocity. We have no pretensions that the trend in velocity is a structural relationship, so that any idea of exploiting this "stable" relationship in the data falls prey to the Lucas critique.

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[16] An explanation used by Bank of Canada researchers (see McPhail and Caramazza, 1990) cites a "balance sheet consolidation" undertaken by households in the early 1980s. It seems plausible that households drew down their liquid assets in order to reduce certain categories of liabilities, such as mortgages. However, the behavioural hypotheses that would yield an explanation of the timing or the permanence of this consolidation are not clear.

Our results leave one of the Bank's most important questions unanswered: How will financial innovation and legislative restructuring affect money demand in the future? Without a model that endogenizes both technological change in the financial sector and the behaviour of legislators, along with their effects on the velocity of circulation in the long run, the question must remain without an answer. If the Bank wishes to use out-of-sample forecasts of money demand as a policy tool, it should be on the lookout for future "exogenous" breaks in trend velocity.[17] Since it is likely that technological change depends on factors that have a much lower frequency than the monthly data used in our study, we are pessimistic about the possibility of endogenizing the effects of financial innovations in a study of money-demand dynamics using monthly data. In addition, the breaking trend that we use to model the long-run behaviour of velocity occurs relatively late in our sample period. The results of our out-of-sample forecasting exercises are fairly encouraging, but forecasts based on our methodology may not be precise because of imprecise estimates of the post-1983 trend in velocity.

Nevertheless, we feel that our results offer several significant contributions with respect to previous Bank of Canada work on the demand for M2 and M2+. Our two-step methodology reveals that the data are compatible with the hypothesis of unit income elasticity of money demand.[18] We feel that the interpretation of long-run elasticities is much clearer in the context of an error-correction model than in a model estimated in first differences. In the latter, long-run elasticities represent the long-run effect on the acceleration of money demand of a change in the rate of growth of an explanatory variable. Our results that interest rates fail to add any significant explanatory power to long-run money-demand equations are compatible with the finding of significant cointegration relationships among short-term interest rates. Since own rates of return move in step with rates of return on competing assets in the long run, changes in individual short-term interest rates do not influence the demand for money in the long run. Deviations of velocity from a breaking trend have strong explanatory power in all of the dynamic money-demand equations that we estimated. We feel that the concept of error correction is potentially important both for generating short-term forecasts and for picking up evidence of future structural breaks.

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[17] In a related study, dealing with the behaviour of the velocity of M2 over an extended time period in several countries, Siklos (1989) finds that the measured effects of proxies for institutional change on velocity become quantitatively small late in the sample. He concludes that this reflects a growing difficulty of the available proxies to measure the true rate of institutional change.

[18] Faig (1989) uses this technique to obtain estimates of the income elasticity of money demand with equations estimated in first differences using quarterly data.

We have not attempted to confront our parsimonious specifications for the demand for M2 and M2+ with those in recent Bank studies, especially McPhail and Caramazza (1990); this would involve comparing non-nested models. In addition, given the complex lag structure of our dynamic equations, we have not been able to tackle the simultaneity problem head on. Future work should address this question. One promising approach involves using seasonally unadjusted measures of the money supply and seasonal dummies as instruments to estimate the impact on money demand of changes in explanatory variables with strong seasonal components. However, we feel that many of the conclusions presented here dealing with the long-run properties of money demand are robust with respect to simultaneity problems.

Data Appendix

We are grateful to the Bank of Canada, and especially to Francesco Caramazza, for generously providing us with the raw data that were used in this study.

To simplify the notation, the same names were used for the variables referred to in this paper as those assigned to the raw data described below. Except for the dummy variables and the interest rates series, the variables used in the paper were all expressed in logarithms.

M2	monetary aggregate M2, average of Wednesdays, seasonally adjusted, millions of dollars (CANSIM B1630)
M2+	monetary aggregate M2+, average of Wednesdays, seasonally adjusted, millions of dollars (CANSIM B1633)
P	consumer price index, not seasonally adjusted (CANSIM D484000)
Y	GDP at constant (1981) prices, seasonally adjusted, millions of dollars (CANSIM I32026)
R90	interest rate on 90-day prime corporate paper, average of Wednesdays, per cent per annum (Bank of Canada)
RUS	interest rate on 90-day commercial paper, average of Wednesdays, per cent per annum (Bank of Canada)
B90	interest rate on 90-day personal fixed-term deposits at chartered banks, average of Wednesdays, per cent per annum (Bank of Canada)
T90	interest rate on 90-day fixed-term deposits at trust and mortgage loan companies, average of Wednesdays, per cent per annum (Bank of Canada)
RM5	interest rate on 5-year fixed-term deposits at banks, average of Wednesdays, per cent per annum (CANSIM B113873)

Data Appendix

RB5	interest rate on 5-year mortgages at chartered banks, average of Wednesdays, per cent per annum (CANSIM B113872)
CSB	real value of outstanding stocks of Canada Savings Bonds $\equiv$ nominal value of the stock divided by the CPI. The nominal value of CSB is measured by its par value in millions of dollars (CANSIM B2406).
P7404	postal strike dummy variable defined as being equal to 1 in April 1974, -1 in May 1974, and 0 in other periods
P7405	postal strike dummy variable defined as being equal to 1 in May 1974, -1 in June 1974, and 0 in other periods
P7510	postal strike dummy variable defined as being equal to 1 in October 1975, -1 in November 1975, and 0 in other periods
P7511	postal strike dummy variable defined as being equal to 1 in November 1975, -1 in December 1975, and 0 in other periods
P7512	postal strike dummy variable defined as being equal to 1 in December 1975, -1 in January 1976, and 0 in other periods
P7811	postal strike dummy variable defined as being equal to 1 in November 1978, -1 in December 1978, and 0 in other periods
P8107	postal strike dummy variable defined as being equal to 1 in July 1981, -1 in August 1981, and 0 in other periods
P8108	postal strike dummy variable defined as being equal to 1 in August 1981, -1 in September 1981, and 0 in other periods
Si	seasonal intercept dummy defined as being equal to 1 in month i, -1 in month i+1, and 0 in other months. The index i takes the values from 1 to 11, corresponding to the months January to November.

Appendix Tables

Table A:1
OLS Estimates of the Error-Correction Model for Money Demand Using M2 as Monetary Aggregate (t-statistics in parentheses)

	$\Delta M2$	$\Delta M2$
Dependent variable	**1970:02-1988:12** **227 observations**	**1970:02-1989:09** **236 observations**
Intercept	0.005609 (4.86)	0.005652 (4.93)
$\Delta M2(-1)$	0.1233 (2.66)	0.1210 (2.63)
$\Delta M2(-3)$	0.1063 (2.16)	0.0916 (1.89)
$\Delta M2(-6)$	0.2608 (5.45)	0.2583 (5.51)
$\Delta M2(-7)$	-0.0783 (-1.68)	-0.0722 (-1.58)
$\Delta M2(-9)$	0.1016 (2.19)	0.1104 (2.42)
$\Delta M2(-12)$	-0.1772 (-3.68)	-0.1645 (-3.45)
ΔP	0.1293 (1.46)	0.1118 (1.28)
$\Delta P(-2)$	0.1353 (1.48)	0.1298 (1.44)
$\Delta P(-6)$	-0.1345 (-1.56)	-0.1227 (-1.44)
$\Delta P(-7)$	-0.2303 (-2.57)	-0.2367 (-2.68)
$\Delta P(-8)$	0.2126 (2.47)	0.2010 (2.37)
$\Delta P(-10)$	0.1946 (2.22)	0.2053 (2.37)

(cont'd)

Table A:1 (cont'd)

	ΔM2	ΔM2
Dependent variable	**1970:02-1988:12** **227 observations**	**1970:02-1989:09** **236 observations**
ΔY	0.1627 (3.47)	0.1602 (3.43)
ΔY(-3)	0.0496 (1.09)	0.0583 (1.29)
ΔY(-4)	-0.0950 (-2.13)	-0.1003 (-2.27)
ΔY(-10)	0.1362 (2.85)	0.1346 (2.84)
ΔY(-11)	-0.1031 (-2.29)	-0.1088 (-2.43)
ΔR90(-1)	-0.001590 (-3.62)	-0.001581 (3.62)
ΔR90(-4)	-0.000782 (-1.66)	-0.000709 (-1.51)
ΔR90(-7)	0.001317 (2.72)	0.001307 (2.71)
ΔR90(-9)	0.001087 (2.65)	0.001114 (2.74)
ΔR90(-10)	0.002230 (2.98)	0.001951 (2.65)
ΔR90(-12)	0.000889 (2.24)	0.000845 (2.15)
ΔB90(-3)	0.000903 (1.45)	0.000921 (1.48)
ΔB90(-6)	-0.001431 (-2.29)	-0.001398 (-2.26)
ΔB90(-10)	-0.002882 (-2.92)	-0.002416 (-2.49)

(cont'd)

Table A:1 (cont'd)

	ΔM2	**ΔM2**
Dependent variable	**1970:02-1988:12 227 observations**	**1970:02-1989:09 236 observations**
ΔCSB	-0.0809 (-11.60)	-0.0815 (-11.86)
P7404	0.009463 (2.92)	0.009308 (2.88)
P7405	0.0104 (3.23)	0.0104 (3.23)
P7510	0.005121 (1.59)	0.004989 (1.55)
P7511	0.006029 (1.88)	0.005885 (1.84)
P7811	0.0131 (4.63)	0.01311 (4.64)
P8107	0.005352 (1.84)	0.005272 (1.81)
S3	-0.002393 (-2.73)	-0.002082 (-2.41)
S4	-0.005070 (-4.17)	-0.004981 (-4.18)
S5	-0.007540 (-5.20)	-0.007656 (-5.37)
S6	-0.007708 (-4.80)	-0.00800 (-5.04)
S7	-0.01098 (-6.31)	-0.01119 (-6.46)
S8	-0.01127 (-6.36)	-0.01129 (-6.41)
S9	-0.01148 (-6.65)	-0.01158 (-6.75)

(cont'd)

Table A:1 (cont'd)

	ΔM2	ΔM2
Dependent variable	**1970:02-1988:12** **227 observations**	**1970:02-1989:09** **236 observations**
S10	-0.01225 (-7.46)	-0.01224 (-7.50)
S11	0.003212 (3.68)	0.003289 (3.78)
B90(-1) - R90(-1)	0.000538 (1.38)	0.000546 (1.43)
B90(-1) - T90(-1)	0.002017 (1.95)	0.001872 (1.84)
IVM2(-1)*	-0.0484 (-4.12)	-0.0486 (-4.15)
$\bar{R}^2$	0.6822	0.6729
$\hat{\sigma}$	0.003567	0.003566
χ^2_{sc} (12)	7.84	9.00
χ^2_{ff} (3)	4.55	4.45
χ^2_{n} (2)	41.48	31.40
χ^2_{h} (1)	0.28	0.16
χ^2_{ARCH} (12)	13.52	12.98
F-test of the restrictions imposed on the general model		
F(43, 138)	1.44	
F(43, 147)		1.40
Chow test Break in 1982:01		
F(40, 141)	1.26	
F(40, 150)		1.13

*Note: IVM2 is deviations of inverse of M2 velocity from breaking trend.

Table A:2
OLS Estimates of the Error-Correction Model for Money Demand Using M2+ as Monetary Aggregate (t-statistics in parentheses)

	ΔM2+	ΔM2+
Dependent variable	**1970:02-1988:12** **227 observations**	**1970:02-1989:09** **236 observations**
Intercept	0.003813 (3.86)	0.003673 (3.76)
ΔM2+(-1)	0.1824 (3.93)	0.1812 (3.96)
ΔM2+(-3)	0.1242 (2.46)	0.1163 (2.37)
ΔM2+(-6)	0.2409 (4.90)	0.2410 (5.00)
ΔM2+(-9)	0.0849 (1.76)	0.0932 (1.97)
ΔM2+(-12)	-0.1350 (-2.78)	-0.1167 (-2.45)
ΔP(-2)	0.06684 (0.96)	0.05778 (0.84)
ΔP(-7)	-0.2193 (-3.33)	-0.2221 (-3.41)
ΔP(-8)	0.1302 (1.97)	0.1154 (1.77)
ΔP(-9)	-0.05703 (-0.90)	-0.07458 (-1.20)
ΔP(-10)	0.09566 (1.51)	0.1070 (1.71)
ΔP(-11)	0.1225 (1.88)	0.1257 (1.94)
ΔP(-12)	0.1626 (2.64)	0.1707 (2.80)

(cont'd)

Table A:2 (cont'd)

	$\Delta M2+$	$\Delta M2+$
Dependent variable	**1970:02-1988:12** **227 observations**	**1970:02-1989:09** **236 observations**
ΔY	0.1399 (4.03)	0.1413 (4.09)
ΔY(-2)	0.03528 (1.01)	0.03483 (1.01)
ΔY(-3)	0.09414 (2.71)	0.1019 (2.97)
ΔY(-10)	0.1172 (3.41)	0.1145 (3.37)
ΔY(-12)	0.0355 (1.09)	0.0403 (1.25)
ΔR90	-0.001437 (-2.51)	-0.001312 (-2.31)
ΔR90(-1)	-0.0009177 (-2.34)	-0.0009116 (-2.35)
ΔR90(-4)	-0.0004348 (-1.29)	-0.0003907 (-1.17)
ΔR90(-6)	0.001127 (1.95)	0.001322 (2.33)
ΔR90(-9)	0.0006576 (2.17)	0.0006912 (2.30)
ΔR90(-10)	0.001121 (2.00)	0.0009037 (1.64)
ΔB90	0.001513 (1.79)	0.001301 (1.55)
ΔB90(-3)	0.0002903 (0.65)	0.0002523 (0.57)
ΔB90(-6)	-0.002154 (-2.59)	-0.002381 (-2.92)
ΔB90(-7)	0.001070 (2.39)	0.001095 (2.47)

(cont'd)

Table A:2 (cont'd)

	ΔM2+	**ΔM2+**
Dependent variable	**1970:02-1988:12** **227 observations**	**1970:02-1989:09** **236 observations**
ΔB90(-10)	-0.001311 (-1.80)	-0.001007 (-1.41)
ΔCSB	-0.06482 (-12.15)	-0.06546 (-12.33)
P7404	0.007026 (2.85)	0.007020 (2.85)
P7405	0.006657 (2.76)	0.006629 (2.76)
P7510	0.004269 (1.82)	0.004127 (1.76)
P7511	0.004634 (2.00)	0.004457 (1.93)
P7811	0.009665 (4.65)	0.009713 (4.68)
P8107	0.004260 (2.00)	0.004136 (1.95)
S2	-0.001537 (-2.41)	-0.001481 (-2.35)
S3	-0.002695 (-3.05)	-0.002429 (-2.79)
S4	-0.005105 (-4.84)	-0.004990 (-4.80)
S5	-0.007712 (-6.60)	-0.007756 (-6.73)
S6	-0.008897 (-7.03)	-0.009276 (-7.43)
S7	-0.01092 (-8.27)	-0.001123 (-8.57)
S8	-0.01106 (-8.40)	-0.01121 (-8.54)

(cont'd)

Table A:2 (cont'd)

	ΔM2+	ΔM2+
Dependent variable	**1970:02-1988:12** **227 observations**	**1970:02-1989:09** **236 observations**
S9	-0.01154 (-9.20)	-0.01171 (-9.37)
S10	-0.01260 (-10.71)	-0.01268 (-10.80)
B90(-1) - R90(-1)	0.001095 (4.93)	0.001037 (5.07)
IVM2+(-1)*	-0.02888 (-3.82)	-0.02955 (-3.91)
$\bar{R}^2$	0.7082	0.7016
$\hat{\sigma}$	0.002620	0.002620
χ^2_{sc} **(12)**	15.79	14.48
χ^2_{ff} **(3)**	2.57	2.20
χ^2_{n} **(2)**	12.06	8.52
χ^2_{h} **(1)**	0.14	0.02
χ^2_{ARCH} **(12)**	6.63	7.21
F-test of the restrictions imposed on the general model		
F(42, 138)	0.63	
F(42, 147)		0.66
Chow test Break in 1982:01		
F(41, 139)	1.18	
F(41, 148)		0.94

***Note:** IVM2+ is deviations of inverse of M2+ velocity from breaking trend.

Appendix Figures

Figure 1: Velocity of M2 and M2+ in Canada (1969:01-1989:09)

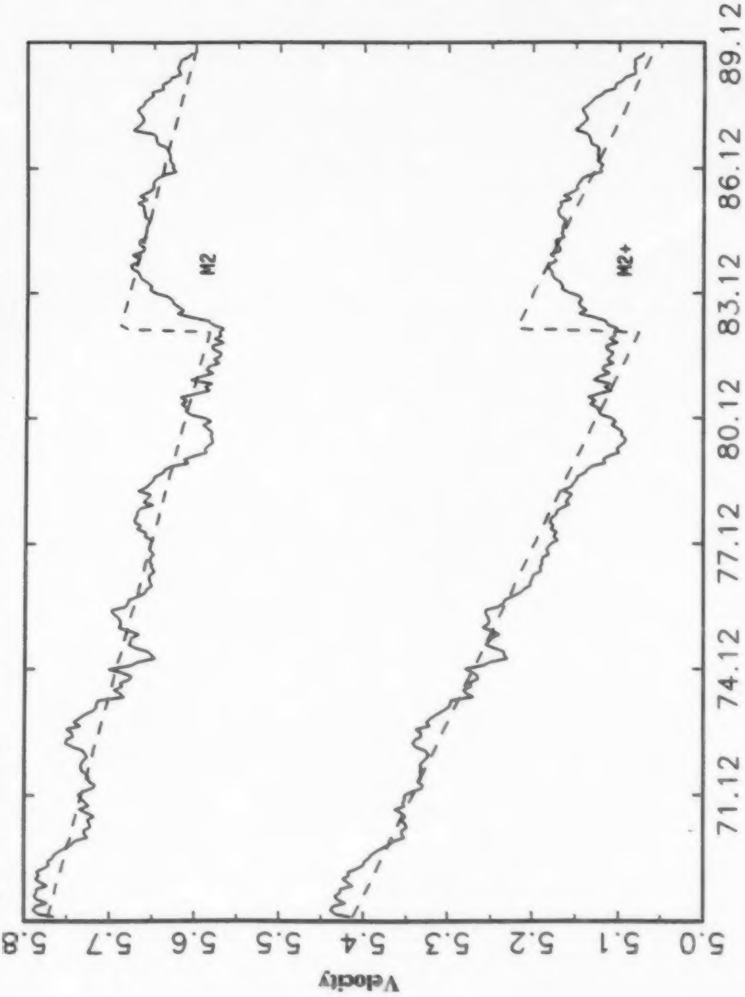


Figure 2
Unit Root Tests of Deviations of M2 Velocity from Breaking Trend

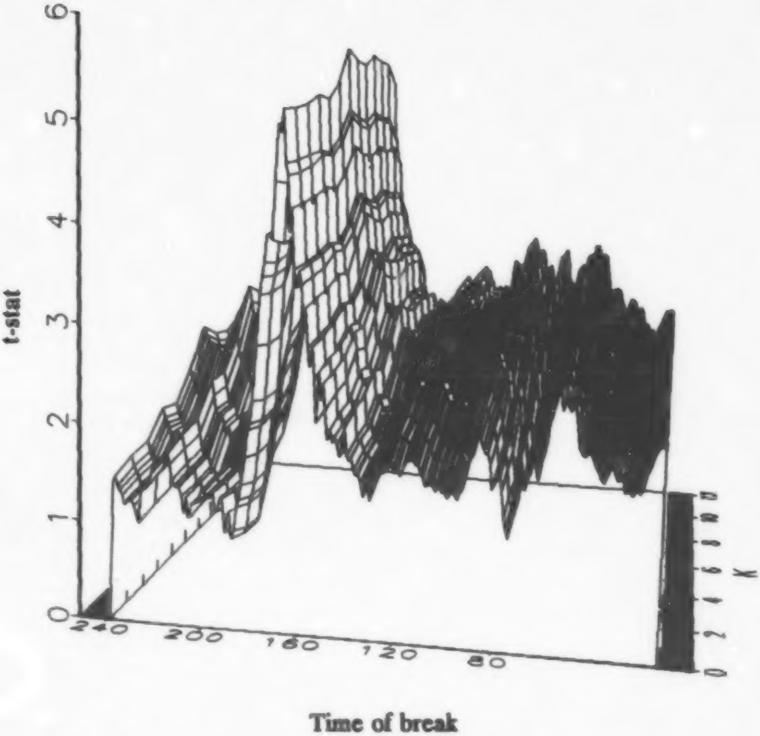


Figure 3
Unit Root Tests of Deviations of M2+ Velocity from Breaking Trend

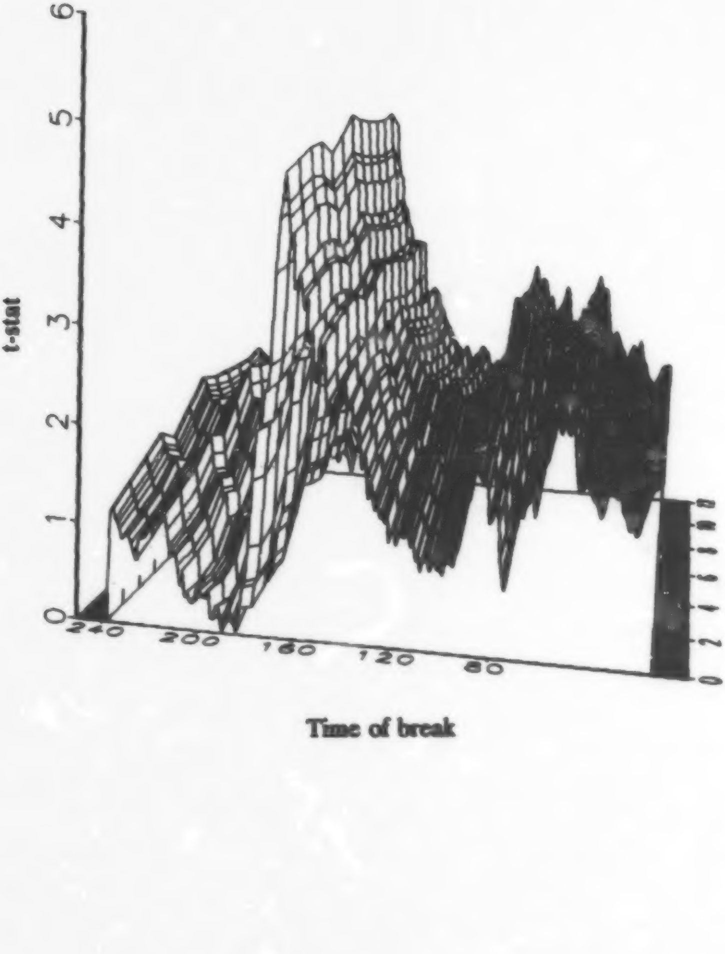


Figure 4
Effect on M2 and M2+ of a 1 Per Cent Rise in Prices
(___M2; — M2+)

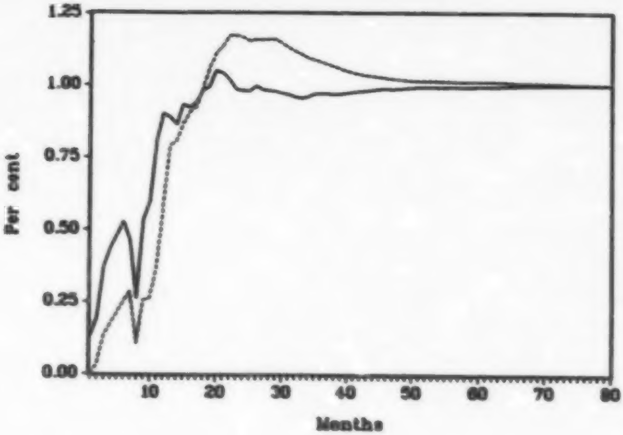


Figure 5
Effect on M2 and M2+ of a 1 Per Cent Rise in Real GDP
(___M2; — M2+)

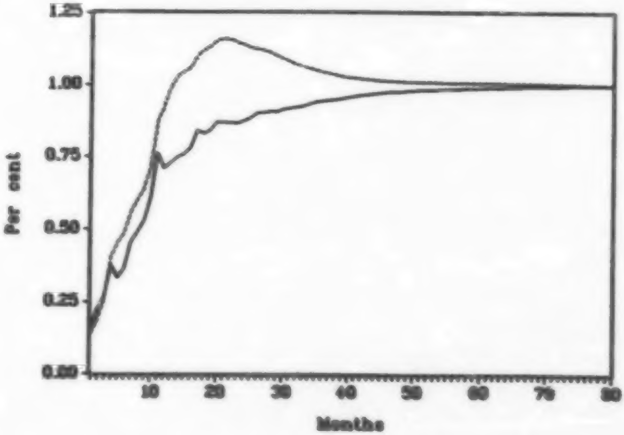


Figure 6
Effect on M2 and M2+ of a 1 Per Cent Rise in the Real Stock of Outstanding CSBs
(____ M2; — M2+)

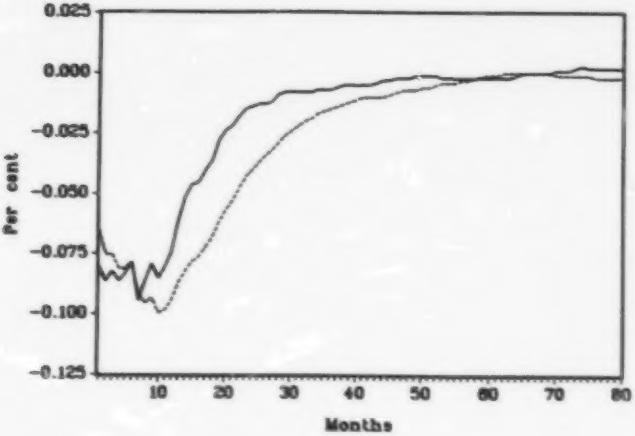


Figure 7
Effect on M2 and M2+ of a 100-Basis Point Rise in R90
(——— M2; —— M2+)

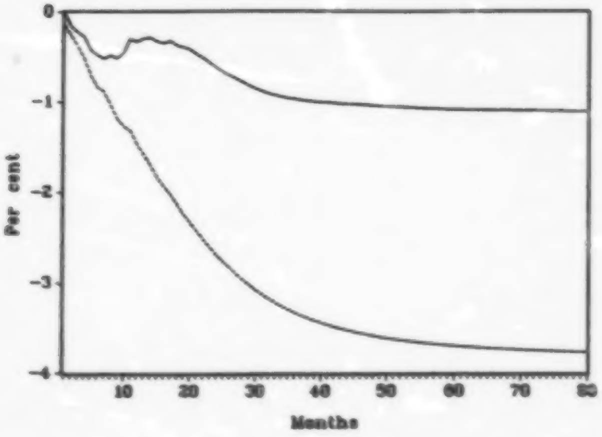


Figure 8
Effect on M2 and M2+ of a 100-Basis Point Rise in B90
(——— M2; ----- M2+)

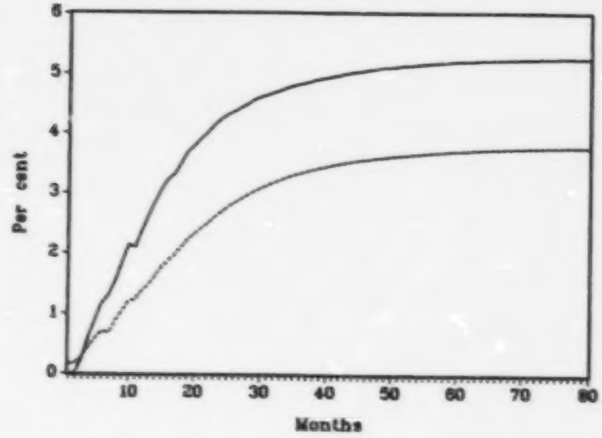


Figure 9
Effect on M2 of a 100-Basis Point Rise in (B90-T90)

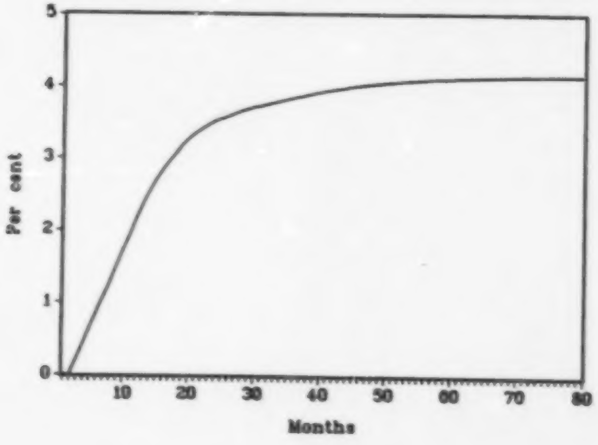


Figure 10
Actual, Predicted and Forecast Levels of M2 (1987:01-1989:09)

——— actual values
------- predicted values based on the estimation: pre-1988:12
- - - - dynamic forecasts: post-1989:01

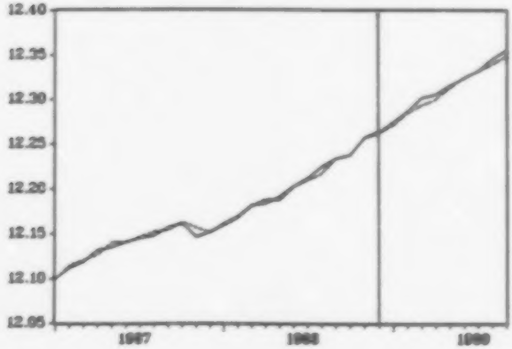
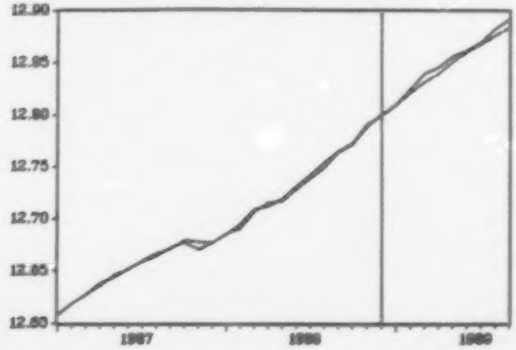


Figure 11
Actual, Predicted and Forecast Levels of M2+ (1987:01-1989:09)

——— actual values
------- predicted values based on the estimation: pre-1988:12
- - - - dynamic forecasts: post-1989:01



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Commentary

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by Jean-Marie Dufour

Steve Ambler and Alain Paquet deal with the modelling of demand for M2 and M2+ in Canada using monthly data for the period from January 1969 to November 1989. The authors explore the implications of a number of concepts and methods recently introduced in the econometrics of time series: unit root tests, breaking trends, cointegration and error-correction models. I believe that this is a useful contribution to the literature on money demand.

In my opinion, the most interesting conclusions of the paper are the following:

- **Univariate analysis of the various time series studied:**

  All of the series seem to be nonstationary and follow an ARMA process in which the autoregressive polynomial has a root equal to one. However, once differenced, the various series appear to be stationary.

- **Univariate analysis of the velocities of M2 and M2+:**

  The velocities appear to be stationary around a breaking trend with the break occurring in January 1983.

- **Estimation of long-run money demand:**

  After analyzing the individual time series, the authors estimate long-run money-demand equations (or cointegration relations) for M2 and M2+. These equations contain as explanatory variables income and a linear trend that shifts in January 1983. Interest rates do not seem to play any role in these demand equations.

- **Estimation of error-correction models:**

  In the context of the foregoing analyses, the authors estimate "money-demand" equations that take the form of error-correction models. These models include as explanatory variables: lagged money growth, present and lagged growth of Canada Savings Bonds (in constant dollars) and of various interest rates, as well as the growth rates of prices and income, binary variables (seasonal factors, postal strikes, etc.) and an error-correction term based on long-run demand. On the basis of Chow-type stability tests, this equation appears stable over time.

Despite the value of these findings, I think it is important, here as elsewhere, to make a distinction between innovation and progress. In order to properly interpret these results, a number of reservations should be noted. My comments will deal with the three major themes of the paper: (i) unit root tests; ii) estimation of long-run demand; and iii) error-correction models.

Unit root tests

Phillips-Perron and Augmented Dickey-Fuller tests are used to test for unit roots in individual series and in the velocity of money (Tables 1 and 2). The authors refer to Perron (1988) for a description of the Phillips-Perron tests. These tests are based on a "non-parametric" correction for autocorrelation. Through a simulation study, Schwert (1989) demonstrated recently that this approach leads to very unreliable tests that reject the null hypothesis far too often in some cases and not often enough (loss of power) in others. For example, even with a large sample (n=250) which follows a process of the form:

$$y_t - y_{t-1} = u_t - \theta u_{t-1}, \; u_t \overset{\text{i.i.d.}}{\sim} N\,[0,\sigma^2]$$

one of these tests, $Z_{\tau\tau}(\ell_{12})$, whose nominal level is 0.05, rejects the null hypothesis with probability 1.00 when $\theta = 0.8$ and with probability 0.014 when $\theta = -0.8$ (see Schwert, 1989, Table 4). Consequently, no conclusions may be drawn from such tests, at least not without a much more in-depth investigation of the structure of the underlying processes. The corrected Dickey-Fuller (1979, 1981) tests and Saïd-Dickey (1984) tests, which are based on a "parametric" correction of autocorrelation, appear to be much more reliable (without, of course, being perfectly satisfactory) provided that the order of the autoregressive process used is sufficiently large.

There is an inconsistency between the conclusions drawn concerning the structure of M2 and Y, and concerning the structure of velocity Y - M2 (the variables are in logarithms). The authors conclude that the variables M2, M2+ and Y are stationary after differencing, which implies that the averages of Y - M2 and Y - M2+ are stationary around a linear trend that changes in 1983: this in turn implies that the averages of $\Delta(Y - M2)$ and $\Delta(Y - M2+)$ cannot be constant. If we accept this result, we must conclude that either ΔY or $\Delta M2$ is not stationary, and similarly for ΔY and $\Delta M2+$. It would certainly have been desirable that the authors re-examine their findings to ensure that they are mutually consistent.

Long-run demand for money

Using binary variables in an econometric equation is rarely a satisfactory solution and using a breaking trend is even less satisfactory. To the extent that "jumps" are unexplained, such variables simply disguise the fact that certain variables are missing. In Table 2.1, we note that the demand for money suddenly declined around 1982-1983. How can we believe that this was unrelated to the movement of interest rates, a variable that was specifically excluded from the demand equation? I think that the authors should explore this possibility further, notably by allowing for nonlinear effects.

It is important to note that the results of Table 2.1 pose difficult problems for statistical interpretation. First, since not all the variables of the equation are integrated (for example, the binary variable), it is not clear that the properties of superconsistence that warrant the use of a two-stage procedure (for the error-correction model) are applicable here; see Stock (1987) on this type of question.

Second, given the presence of binary variables, it would be necessary to make additional assumptions concerning the nature of the change in regime to find an asymptotic distribution.

Error-correction models

As was mentioned above, insofar as it is not clear that all the coefficients of the long-run demand equation converge at a rate faster than $\sqrt{n}$, the t-statistics presented with this equation may be affected by a fairly common problem of errors in variables. This type of problem usually leads to an overestimate of the significance level of the results (Pagan, 1984, 1987).

The method used to simplify the equation by removing the variables whose t-statistics are lower than 1, does not in general lead to a consistent estimator of the model. It would have been preferable here to use a consistent information criterion, such as the Schwarz criterion or the Hannan-Quinn criterion.

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Commentary

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by Steve Poloz

I enjoyed reading this paper. The authors are to be commended for covering some tough ground in a reasonably readable piece.

They take what I consider to be a very old problem - so old that I thought it was old when I wrote my undergraduate thesis on it - and apply a sophisticated array of tests in the hope of generating some useful answers. While the technology used is of the highest order, in certain areas the application is a little less so. Usually this is the result of stretching the technology beyond its known limitations, but I think it is important to consider the implications of making the opposite inferences in such instances.

In reading the paper I was struck by the number of occasions when the data were judged to be "roughly compatible" with a particular hypothesis, or parameters were described as "somewhat significant," especially when such inferences are made and retained as part of the maintained hypothesis while testing another variant. One cannot help but wonder what has been learned by the end of the investigation.

Let's just take a quick look at the series of inferences made in the paper and reconsider what, in fact, has been demonstrated.

- *The levels of the series have unit roots.* Most of us are familiar with this result, which is usually evident from a graph; the inference is checked informally to make sure it is not due to discrete shifts.

- *The first differences are stationary.* This, too, is a fairly well-known result.

- *The velocity of M2 and M2+ contains a unit root.* This is evident from a graph, but the same graph shows a discrete shift in the sample; after some searching, a "breaking trend" is developed around which the deviations of velocity are found to be stationary.

At this point I might have been a little concerned about the validity of the velocity concept being used. The authors explore whether the income elasticity in velocity should be constrained to unity. They fit some regressions that suggest otherwise; however, inference in this case is considered to be "complicated" and, while they obtain somewhat stronger rejections of the unit root hypothesis when the income elasticity is allowed to differ from unity, they regard this as unconvincing and declare that the results are "roughly compatible" with a unit income elasticity. This result is then incorporated thereafter.

It seems to me that this inference is crucial, and should not be taken lightly. Inspection of the velocity charts indicates that there may be a unique, non-unitary income elasticity for which velocity would be stationary. And given that the authors are dealing with broad definitions of money, I see no reason to favour a unit elasticity *a priori*.

A similar approach is used to demonstrate that interest rates do not belong in the long-run demand-for-money equation. Basically, a series of residuals is found to contain no unit root, and adding more variables to the relationship does not affect that property, so the data are judged to be "compatible" with the exclusion of interest rates. This was surprising to me, given that M1 is quite interest-elastic and constitutes some 15 per cent of M2 and 10 per cent of M2+.

In this regard, I wonder why the authors do not consider that movements in CSBs have a permanent effect on money holdings. I think they should have been treated as part of the cointegrating vector. The other inferences are undoubtedly affected by this omission.

The authors go on to estimate an error-correction model for nominal balances. I like the way they use only two steps, rather than iterating to test down.

The important result here is that the deviation of velocity from its breaking trend is significant in the regression. This tells us that error correction occurs - that there is an adjustment process that takes us to a steady-state trend line. However, I am not so sure of this result. Notice that the 1982-84 shift in money demand - the so-called "consolidation period" - is captured by their breaking trend. This means that in the steady state, velocity converges on the broken trend line. Since we know that successful M2 and M2+ equations must include something to capture this shift, and in this case it is part of the error-correction term, we should not be surprised that the latter is statistically significant. It would have been better to enter the shift separately so the error-correction term would compete for significance more fairly. Doing so might seriously affect the authors' estimate of the so-called "speed of adjustment," in particular.

Compared to what I have seen previously, the models simulate the data for 1989 extremely well. If this were the only criterion, I would have to compliment the authors. But I am concerned that the fundamental questions about money demand - the income elasticity, the interest rate elasticity, whether long-run price homogeneity holds, whether currency substitution is important, whether simultaneity is present, and so on - remain unanswered.

It almost seems as if the more sophisticated our tests become, the more aware we are of the extent of our ignorance about basic economic relationships. That is not very reassuring, except in the sense that a fuller appreciation of the extent of that ignorance should reduce the scope for policy error.

General Discussion

Apostolos Serletis asked whether it was appropriate to use monthly data to test for cointegration given that cointegration concerns the long-run relationships between the variables of interest. He wondered whether Ambler and Paquet's conclusion that velocity is stationary around a break in trend in the early 1980s would be corroborated with quarterly data. Paquet replied that, while the dynamic properties of monthly money-demand models would likely differ from those of quarterly models, in principle, if cointegration exists in a monthly model, it will also be present in a quarterly model.

Serletis also noted that the price variable used in Ambler and Paquet's model, the CPI, is much more sensitive to exchange rate movements and may have different long-run properties (two unit roots rather than one) than the GDP deflator. He asked whether the authors had estimated their model using this alternative price variable. Steve Ambler responded that monthly data for the GDP deflator are not available and that he preferred to use the CPI rather than a monthly interpolation of the GDP deflator.

Pierre Fortin returned to the issue of the long-run income elasticity of money demand raised by Steve Poloz in his discussion of the authors' results. He asked whether the unitary long-run elasticity had been imposed as a result of theoretical considerations and whether the authors had estimated error-correction models in which this constraint was relaxed. Ambler replied that they had not estimated dynamic specifications without this constraint given that the cointegration analysis in the first stage of their results indicated that velocity was stationary (around a breaking trend). They did not consider a unitary long-run income elasticity to be a theoretical requirement, but noted that testing this constraint was difficult because of the non-standard distribution theory involved. However, recent econometric developments that would allow this constraint to be tested were considered worth pursuing.

Charles Freedman asked what kinds of factors based on portfolio theory could explain the downward trend in M2 velocity over the most recent 25 years (such as trends in interest rate differentials or expansions of balance sheets). Ambler responded that technological change and financial innovation provide one possible explanation of the trend. He noted that, for M1, recent work by Pierre Siklos over a much longer period suggested that certain proxies for these effects appeared to explain some of the trend in the earlier part of the century, but were less successful in the more recent period.

Charles Adams asked whether any series other than velocity had been tested formally for a break in trend, noting that such evidence might provide an indication as to the underlying cause of the shift in velocity identified by the authors. Ambler replied that no formal tests for breaks in trends in other series had been performed although visual and informal evidence such as the pattern of the cumulative sum of squared residuals had been examined.

Charles Freedman remarked that it was difficult to know whether the break in velocity in the early 1980s reflected a permanent shift in its level or in its rate of growth. Ambler replied that such inference was fragile, but that their results indicated a permanent shift in level with a return to the pre-break rate of growth.

Pierre Duguay commented that the dating of the breakpoint was undoubtedly sensitive to the procedure used to detrend velocity and suggested that if a nonlinear trend (for example, the inverse of time) were used, the unusual episode in velocity might well appear to be a "bubble" in the late 1970s and early 1980s rather than the upward shift identified in 1982-84. Bruce Montador also wondered whether the break in M2 velocity was related to the abandonment of M1 targets that occurred in the early 1980s.

Pierre Fortin commented that it would be interesting to consider whether allowing the real and inflation-premium components of nominal interest rates to have separate effects on money demand could help give the shift in velocity some economic interpretation. Daniel Racette noted that the break in velocity occurred at about the time that inflation fell significantly. The resulting "re-entry problem" (whereby lower inflation and a lower level of nominal interest rates induces an increase in the level of real balances demanded) should have generated a downward, rather than an upward shift in velocity at that time. Peter Howitt remarked that the real *demand* for M2 might increase under such situations but would not be discernible in the data if the *supply* had decreased (i.e., if the shift in demand had not been accommodated). Charles Freedman argued that the re-entry issue is relevant to M1 demand, which is fairly sensitive to interest rates, but not to M2 demand for which the effect of a change in the general level of interest rates is negligible.

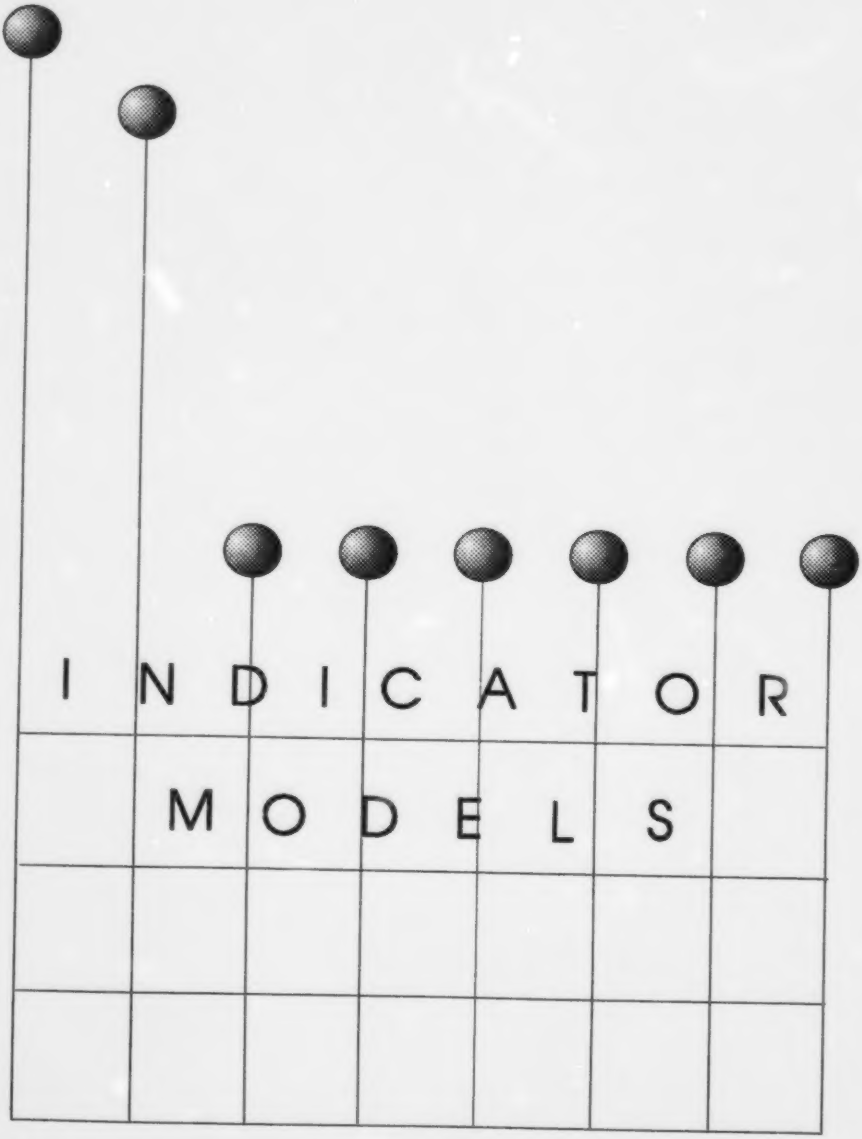
John Murray remarked that, owing to the heterogeneity of their components, the simple-sum aggregates M2 and M2+ have only limited theoretical appeal. Because of the resulting aggregation problems, he suggested that there might be little payoff to investing much effort towards explaining "wiggles" in monetary aggregates that have such a dubious link to the concepts to which economic theory applies (although he noted that in a world of ongoing change and financial innovation, the more theoretically appealing Divisia aggregates might encounter similar problems of interpretation).

Gregor Smith asked whether there was any evidence of cointegration in money-demand models based on Divisia indices or for narrower aggregates such as M1. Doug Hostland responded that, when a much longer sample period was considered, there was evidence of cointegration for M1 until about 1980 when financial innovations generated large shifts in that aggregate.

However, there is no evidence in favour of the stationarity of the velocity of M1A, a slightly broader aggregate that internalizes those shifts. He also noted that for M2, the Bank Act of 1967 had measurably altered the behaviour of velocity. The Divisia indices are only available from 1968, so no evidence is available for those aggregates over the longer sample period.

Paul Boothe remarked that his "priors" were that velocity should be stationary. Steve Ambler and Pierre Duguay took the opposite view, arguing that velocity was very much a function of technological change as reflected in financial innovations (new deposit instruments, etc.), and that such change is stochastic and occurs in spurts. Ambler added that the unit root hypothesis might be difficult to distinguish empirically from that of trend stationarity subject to occasional permanent random shocks. Duguay commented that legislative changes such as the 1967 Bank Act also contribute to permanent shocks to velocity.

Simon Van Norden noted that if there were enough transitory noise (for example, measurement error) in the data, the Phillips-Perron tests might spuriously conclude that cointegration exists. Ambler agreed that, in finite samples, such factors could be a problem.



INDICATOR MODELS

THE INFORMATION CONTENT OF FINANCIAL AGGREGATES DURING THE 1980s

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by Patrice Muller*

Introduction

It is frequently argued in the economic literature and in the financial media, particularly in the United States, that the traditional relationship between total spending and the standard financial aggregates broke down in the late 1970s and early 1980s. The most commonly advanced explanation for this development is the process of financial innovation and deregulation of the financial industry during this period.[1]

In Canada, on the other hand, the legislative and regulatory environment did not change significantly in the early part of the last decade. The innovation that did occur in the financial industry was more a series of spontaneous responses to a wide range of forces than a reflection of an evolving legislative framework. These forces included high inflation and

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[1] See Akhtar (1983) for a survey of the effects of financial innovation on the demand for money in the major industrialized countries. It should be noted, however, that some recent research - Darby, Mascaro and Marlow (1989), Lucas (1988) and Rasche (1987) - indicates that, in certain cases and contrary to the results of previous studies, the traditional relationship between monetary aggregates and nominal spending does not seem to have broken down in the early 1980s.

* *The author has profited from research carried out in the Department of Monetary and Financial Analysis at the Bank of Canada by Allan Crawford, Doug Hostland, Leslie Milton, Richard Laver, Steve Poloz, and Paul Storer. The author wishes to thank Pierre Duguay, Charles Freedman, David Longworth and all his other colleagues for their comments and encouragement, as well as Rodney Schmidt and Brian Ridgeway for their technical assistance.*

Figure 1

Velocity of M1

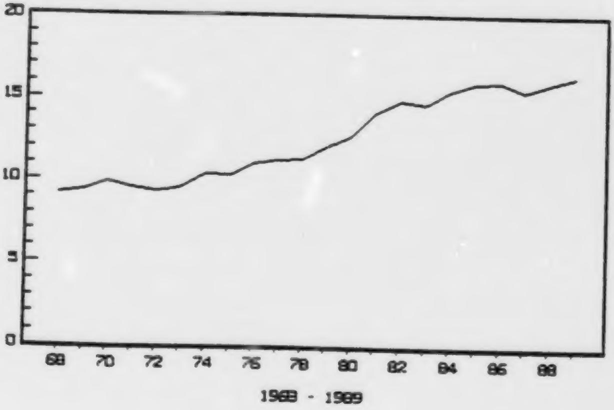
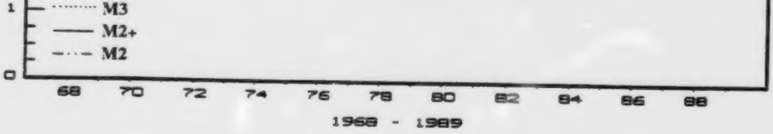


Figure 2

Velocity of M2, M2+, M3, and M3+



Refer to Appendix 1 for data sources.

interest rates, rapid technological progress in the production of financial services and increased competition among the different financial pillars (Freedman, 1983).

While the changes were more gradual in this country, the relationship between some of the financial aggregates and total spending was not totally stable, as shown by the following velocity charts of various money and credit aggregates (Figures 1 through 4).

Of the many financial innovations that have affected the stability of the relationship between the various financial aggregates and total spending, the following should be noted:

- The spread of daily interest chequable accounts and daily interest non-chequable savings accounts over the first half of this decade, which has to some extent affected the demand for the narrow monetary aggregate, M1. The unpredictable nature of this type of change led the Bank of Canada to announce in November 1982 that it would no longer set formal growth-rate targets for M1 (Bank of Canada, 1983).
- Balance sheet consolidation by households and firms over 1982-84. During this period, economic agents apparently used part of their liquid assets, including bank deposits, to reduce their indebtedness (Bank of Canada, 1985). This resulted in a permanent downward shift in the demand for M2 (McPhail and Caramazza, 1990) and was also reflected in a lower level of household and business credit aggregates.
- The rapidly growing public debt, coupled with a reduction in transactions costs for the purchase of treasury bills by households, led to a shift of households' liquid assets[2] to treasury bills and Canada Savings Bonds and away from deposits in financial institutions (Table A1.1 in Appendix 1).
- Increased use by businesses of the short-term capital market (commercial paper and bankers' acceptances) over the last half of this decade, which resulted in a decrease in bank loans (Table A1.2 in Appendix 1). This has reduced the need for banks to attract deposits, particularly wholesale deposits.

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[2] Households' liquid assets include their deposits in financial institutions, Canada Savings Bonds and treasury bills.

While certain financial innovations have primarily affected the distribution of deposits among the various monetary aggregates so that their effects are internalized in the broadest aggregates,[3] the effect of other innovations appears to have been to reduce the demand for services supplied by financial intermediaries. In other words, these innovations have produced a simultaneous decline in the demand for bank and near-bank credit and in the demand for deposits with financial intermediaries.

The net effect of the financial innovations that occurred in the 1980s has been to reduce the share of M1 in the broad monetary aggregates and to reduce the share of the broad monetary aggregates in a broader liquidity aggregate comprising all deposits in financial institutions and all short-term public and private instruments not held by financial institutions (Table 1 and Figure 5).

The instability of the relationship between total spending and the various financial aggregates has led some economists to conclude that these aggregates are no longer useful for the conduct of monetary policy.[4] The purpose of the present study is to investigate whether, despite these developments, Canadian financial aggregates still have a valuable role to play in the formulation of monetary policy. Rather than making the same stringent demands of monetary aggregates that were made in the 1970s (i.e., providing intermediate targets), we will limit ourselves in this study to investigating the possibility that financial aggregates contain information on economic activity that makes them a valuable source of information for the formulation of monetary policy.[5]

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[3] Freedman (1983) and Fine (1990, background paper in this volume) describe in detail the innovations that have led to shifts in deposits among the monetary aggregates.

[4] See, for example, B. Friedman (1988a and 1988b).

[5] See McCallum (1989) for an in-depth review of the various roles of the monetary aggregates in the formulation of monetary policy.

Figure 3

Velocity of Household Credit Aggregates

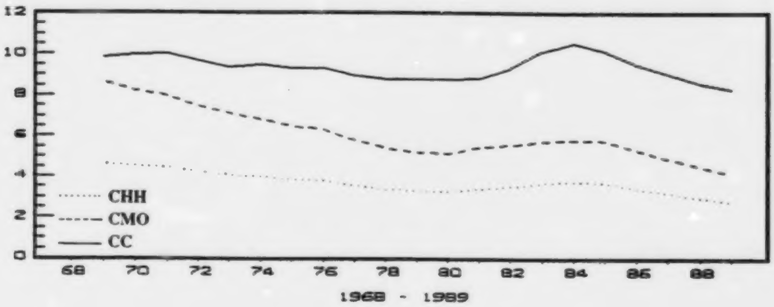
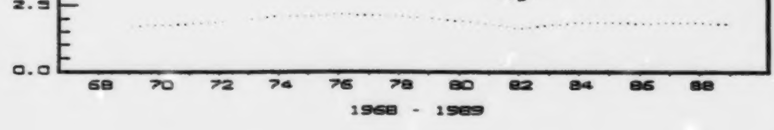


Figure 4

Velocity of Business Credit Aggregates



Household credit: CHH = total household credit, CMO = mortgage credit, CC = consumer credit
Business credit: BL = bank loans, STBC = short-term business credit, TBC = total business credit.
Refer to Appendix 1 for data sources.

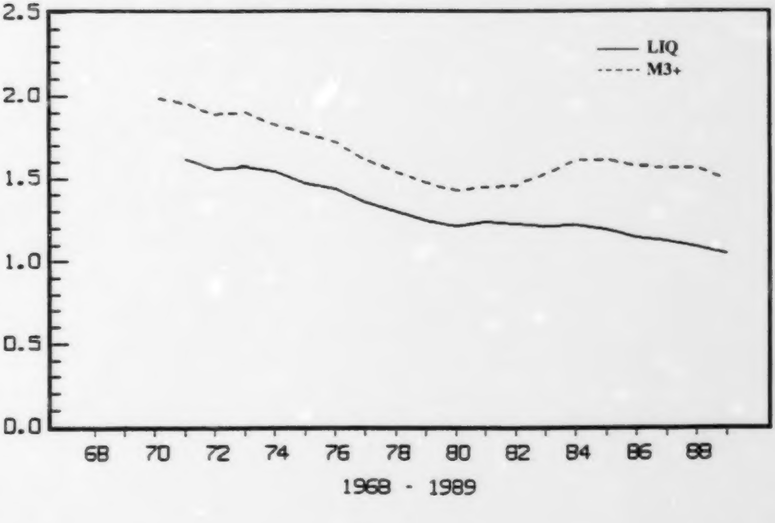
Table 1
M3+ and Total Liquidity
Components as per cent of total, total in millions
(End-of-period data)

	1971Q4	1975Q4	1980Q4	1985Q4	1989Q4
M3+	81.4	82.1	83.9	72.5	69.6
CSB + T.B.	14.0	12.0	8.9	20.7	20.3
Other	4.6	5.9	7.2	6.8	10.2
Total	63,218	123,478	269,127	416,999	614,589

Sources: M3+ = M3 + (M2+ - M2) - deposits of trust and mortgage loan companies with banks (B1705); CSB + T.B.= Canada Savings Bonds (B2406) + treasury bills held by individuals (B2477) - treasury bills held by trust and mortgage loan companies (B1708); Other = outstanding treasury bills (excluding federal government securities) and other private and public short-term instruments (B15023) - instruments held by banks (B442+B471) - instruments held by trust and mortgage loan companies (B1707+B1709).

Figure 5

Velocity of M3+ and a Broad Liquidity Aggregate Including all Deposits at Banks and Near-Banks and all Short-Term Paper



Section 1 explains in greater detail why financial aggregates can be useful sources of information and why monetary aggregates and credit aggregates are both worth considering. Using correlation coefficients, Section 2 examines the contemporaneous relationship between various financial aggregates and total spending and the intertemporal relationship between various aggregates, total spending and the price and volume components. Section 3 studies the information contained in the financial aggregates in greater depth by estimating indicator models and examining their stability. The predictive performance of these indicator models during the 1980s is then analyzed in Section 4. Section 5 investigates the possibility that indicator-model forecasts contain information on economic activity not provided by the first release of the national accounts by Statistics Canada. Following this, the possibility that indicator models yield information not supplied by economic forecasts offered in the marketplace is explored in Section 6. Some general conclusions are then presented in the final section.

1. Are Financial Aggregates Good Sources of Information?

Economic agents hold currency and deposits in financial institutions for two main reasons: to facilitate commercial exchange among themselves and to invest a portion of their savings. In both cases, movements in nominal income play an important role in determining the level of money balances that these economic agents wish to hold.[6] Similarly, economic agents borrow (i.e., apply for credit) to carry out commercial transactions. Once again, movements in nominal income are an important determinant of credit developments. Generally speaking, therefore, developments in nominal income and financial aggregates should follow a similar course. If a relationship between certain financial aggregates and nominal income could be established statistically, this link could be used to obtain valuable information on underlying economic activity since data on most financial aggregates become available much more quickly than national accounts data. The aim is not to establish a causal link[7] between financial aggregates and economic activity, but simply to exploit any stable relationship that can be identified between them.

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[6] Naturally, other factors (notably, interest rates) influence the decisions of economic agents. In most cases, however, nominal income is the most important factor, and it is this link that is exploited when financial aggregates are used as sources of information.

National accounts data (nominal GDP, real GDP and the GDP deflator) are usually released two months after the end of a quarter, the only exception being first-quarter data, which are not released until almost three months after the end of the quarter. On the other hand, complete quarterly data on most financial aggregates are available one or two weeks after the end of a quarter.[8] If a stable and contemporaneous relationship could be established between a financial aggregate and a macroeconomic aggregate, it would be possible to use this link to infer developments in the macroeconomic aggregate one or two weeks after the end of a quarter - i.e., almost a month and half before Statistics Canada's figures are released. Furthermore, if a relationship could be established between the behaviour of a financial aggregate in quarter t and the behaviour of a macroeconomic aggregate in quarter t+1, it would mean that information on the behaviour of this macroeconomic aggregate in quarter t+1 would be available about nine days after the new quarter begins - and almost five and half months before the national accounts data are released.

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[7] The present study is far less ambitious than many others that have tried to establish a causal link between money and credit, on the one hand, and economic activity, on the other. See, for example, Sims (1972, 1980). Given this limitation, the results should be more robust and less subject to refutation than causality studies (see Stock and Watson, 1989 for an overview of the contradictory results on causality studies), since the goal is limited to establishing a stable link between financial aggregates and economic activity, irrespective of the direction of causality.

[8] The only exceptions are quarterly data on household credit (consumer and mortgage loan credit) and M2+ data, which only become available some two months after the end of the quarter. Bank data on household credit, however, are available one or two weeks after the end of a quarter.

With credit being the counterpart of money on the balance sheets of financial intermediaries, one may wonder why there is any reason to consider both monetary and credit aggregates. Although they are by definition equal at the broadest macroeconomic level, this is not the case for the monetary and credit aggregates published by the Bank of Canada and used in this study. As shown in Table 2, there are several differences between the various aggregates.

For one thing, the universes covered by the different aggregates are not identical. For example, the broadest monetary aggregates (M2+ and M3+) include some liabilities of banks, trust and mortgage loan companies, *caisses populaires*, and local credit unions, while household credit aggregates include some assets of banks, trust and mortgage loan companies, life insurance companies, finance and consumer loan companies, and department stores. In the case of business credit, on the other hand, a large share of the funds borrowed by business does not even appear on financial intermediaries' balance sheets (e.g., commercial paper, bankers' acceptances, stocks and bonds).[9] The fact that the various aggregates can follow quite different patterns over time is, to a large extent, a result of these differences in coverage.

In addition, narrower aggregates covering the same universe of financial intermediaries (such as banks) may also evolve quite independently, since each represents only one part of these intermediaries' balance sheets. Even in the case of the broadest monetary aggregate on the banks' balance sheets (i.e., M3 minus currency outside banks), and the broadest credit

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[9] Financial institutions hold some corporate securities that they acquire in financial markets. The amount of securities held by financial intermediaries is quite low, however, since the basic purpose of security issues is to avoid financing by financial intermediaries.

Table 2
Monetary and Credit Aggregates: Coverage

Millions of dollars, monthly average of Wednesdays and month-ends
June 1989 (raw data)

Assets					Liabilities
		Central Bank			
			Currency outside banks	**17,807**	
		Banks			
		Household credit	Net demand deposits	**21,719**	
80,734		Mortgage credit (CMO)			M1 39,315
58,629		Consumer credit (CC)			
139,363		Total (CHH)			
		Business credit, short-term	Individual savings accounts, notice deposits other than personal accounts	**186,930**	
96,222		Bank loans (Can. $) (BL in STBC)			M2 226,245
25,819		Foreign currency loans$^{(1)}$ (STBC)			
9,384		Other (STBC)	Wholesale deposits, foreign currency deposits by residents	**45,525**	
131,425		Total (STBC)			M3 271,770
13,643		**Business credit, long-term** (LTBC)	Private-sector instruments in process of clearing	-1,014	
	248,431	**Other assets**	**Other liabilities**	257,579	
	{143,416}	Of which: foreign currency assets net of foreign currency business loans	Of which: foreign currency liabilities net of foreign currency deposits by residents	{172,228}	
	528,335	**Total assets**	**Total liabilities**	528,335	
		Trust and mortgage loan companies			
70,393		**Household credit (CHH)**	Deposits added to M2 to obtain M2+	**84,257**	
62,773		Mortgage credit (CMO)			
7,620		Consumer credit (CC)	Other liabilities	15,727	
8,449		**Business credit, short-term** (LTBC)			
228		**Business credit, long-term** (LTBC)			
	19,995	**Other assets**			
	99,984	**Total assets**	**Total liabilities**	99,984	

(cont'd)

Table 2 (cont'd)
Monetary and Credit Aggregates: Coverage
Millions of dollars, monthly average of Wednesdays and month-ends
June 1989 (raw data)

Caisses populaires and local credit unions(2)

Assets		Liabilities		
		Deposits and share capital added to M2 to obtain M2+	**58,174**	
64,742	**Assets**	Other liabilities	6,568	
64,742	**Total assets**	**Total liabilities**	64,742	
			M2+	**387,822**
			M3+	**433,347**

Other sources of financing(2)

	Households
13,637	Mortgage credit, life insurance companies (CMO)
853	Mortgage credit, finance and consumer loan companies (CMO)
2,770	Consumer credit, life insurance companies (CC)
7,019	Consumer credit, finance and consumer loan companies (CC)
2,670	Consumer credit, major stores (CC)
	Businesses
56,660	Commercial paper of non-financial businesses (STBC)
148,011	Stocks and bonds (LTBC) net of securities held by financial institutions

Summary

	Household credit		
78,707	Consumer (CC)	M1	**39,316**
157,997	Mortgage (CMO)	M2	**226,245**
236,705	Total (CHH)	M3	**271,770**
		M2+	**387,822**
	Business credit	M3+	**433,347**
197,493	Short-term (STBC)		
161,881	Long-term (LTBC)		
359,374	Total (TBC)		
	Total credit		
596,079	CHH + TBC		

Source: *Bank of Canada Review*, Tables C3, C4, D2, D3, E1, E2, E3 and F3

1. Data corrected for exchange rate variation
2. End-of-quarter data

aggregate (i.e., the sum of bank credit to households and to businesses), the two aggregates may still evolve independently because banks can adjust their other asset and liability items to balance their books.

The correlation coefficients between the quarterly growth rates of selected aggregates shown in Table 3 testify to the lack of a close link between movements in monetary aggregates and credit aggregates. Quarterly growth in M1 is only weakly correlated with growth in the broader monetary aggregates and the various credit aggregates, and is negatively correlated with the growth of business credit.

Quarterly growth in the broader monetary aggregates (M2, M3 and M2+) follows the growth of household and business credit aggregates more closely. The link is far from perfect, however, since the correlation coefficients generally fall between 0.4 and 0.7. It is also interesting to note that the correlation coefficient between growth in M2 and M3 never exceeds 0.75, while growth in M2 and M2+ is more closely correlated. Growth of M3 is more closely related to growth of M2+ than to growth of M2.

The various household credit aggregates do not always move in step, and their growth is, at best, only very weakly correlated with growth in business credit aggregates. Growth of the household credit aggregates is more closely related to growth of M2+ (and M3) than to growth of M2. In contrast, growth of total business credit seems to be more closely linked to growth of M2 than to M2+. Finally, growth of business credit is more closely linked to M3 growth.

It is clear from this brief review of the correlation coefficients between the quarterly growth of the different monetary and credit aggregates, that these aggregates can move independently. Thus it makes sense to study both types of aggregates when trying to determine the information they contain.

Table 3
Correlation Coefficients Between Quarterly Growth Rates of Various Monetary and Credit Aggregates in Different Periods

		M1	M2	M3	M2+	CHH	CMO	CC	BL	STBC	TBC
M2	71Q2-89Q4	0.32									
	71Q2-79Q4	0.10									
	80Q1-89Q4	0.28									
M3	71Q2-89Q4	0.09	0.73								
	71Q2-79Q4	-0.34	0.57								
	80Q1-89Q4	-0.03	0.71								
M2+	71Q2-89Q4	0.36	0.94	0.82							
	71Q2-79Q4	0.10	0.95	0.61							
	80Q1-89Q4	0.30	0.94	0.77							
CHH	71Q2-89Q4	0.37	0.49	0.64	0.66						
	71Q2-79Q4	0.26	0.40	0.41	0.49						
	80Q1-89Q4	0.25	0.30	0.46	0.47						
CMO	71Q2-89Q4	0.36	0.45	0.62	0.63	0.97					
	71Q2-79Q4	0.09	0.41	0.48	0.52	0.86					
	80Q1-89Q4	0.27	0.19	0.33	0.37	0.96					
CC	71Q2-89Q4	0.34	0.50	0.61	0.62	0.90	0.76				
	71Q2-79Q4	0.39	0.25	0.19	0.29	0.81	0.41				
	80Q1-89Q4	0.17	0.43	0.57	0.54	0.89	0.73				
BL	71Q2-89Q4	-0.25	0.42	0.66	0.44	0.31	0.24	0.41			
	71Q2-79Q4	-0.20	0.25	0.53	0.21	0.40	0.35	0.33			
	80Q1-89Q4	-0.57	0.31	0.62	0.28	0.04	-0.11	0.26			
STBC	71Q2-89Q4	-0.18	0.63	0.68	0.59	0.38	0.30	0.48	0.82		
	71Q2-79Q4	-0.33	0.49	0.59	0.40	0.37	0.36	0.26	0.63		
	80Q1-89Q4	-0.38	0.59	0.61	0.50	0.15	-0.01	0.38	0.84		
TBC	71Q2-89Q4	-0.29	0.54	0.52	0.46	0.18	0.10	0.29	0.69	0.86	
	71Q2-79Q4	-0.51	0.37	0.45	0.32	-0.15	-0.05	-0.25	0.13	0.53	
	80Q1-89Q4	-0.34	0.59	0.57	0.50	0.13	-0.02	0.35	0.81	0.97	
LL	71Q2-89Q4	0.22	0.59	0.88	0.73	0.67	0.66	0.61	0.52	0.53	0.34
	71Q2-79Q4	-0.13	0.42	0.79	0.43	0.32	0.33	0.20	0.33	0.55	0.43
	80Q1-89Q4	-0.07	0.44	0.79	0.56	0.49	0.41	0.54	0.38	0.32	0.25

CMO = residential mortgage credit, CC = consumer credit, CHH = total household credit, BL = bank business credit, STBC = short-term business credit, TBC = total business credit, LL = total liquidity. (Refer to Appendix 1 for data sources.)

2. Temporal Relations Between Financial and Macroeconomic Aggregates

2.1 Contemporaneous link

Before beginning an econometric analysis of the relationship between the growth of the various financial and macroeconomic aggregates, it would perhaps be useful to derive some stylized facts that can guide the empirical research.

On the basis of the correlation coefficients between the four-quarter growth in nominal GDP, real GDP and the GDP deflator and the four-quarter growth of various financial aggregates, it would appear that the broad monetary aggregates (M2, M3, M2+, M3+, and LL[10]) are the most closely correlated contemporaneously with nominal GDP over the 1971Q1-1989Q1 period (Table 4).[11] The stability of the M2 and M2+ equations and the close, long-term correlation between M2, M2+ and nominal spending, prompted the Bank of Canada to follow developments in M2 and M2+ very closely.[12] This correlation appears to weaken over the last half of the 1980s, a period that covers only one-half of a business cycle.[13]

The growth of bank consumer credit seems to be the best contemporaneous indicator for real GDP growth over the 1971Q1-1989Q1 period. This result holds no matter whether nominal or real financial aggregates are used (the latter being deflated by the GDP deflator). Moreover, bank consumer credit remains the best indicator over the various subperiods analyzed in Table 4.

Lastly, short-term business credit is the best contemporaneous indicator of growth in the GDP deflator over the 1971Q1-1989Q1 period, as well as over the two major subperiods (1971Q1-1980Q4 and 1981Q1-1989Q1). M2 follows this credit aggregate closely for these periods. Over the latter half of the past decade, however, these two aggregates were fairly poor indicators and were largely dominated by the various household credit aggregates and by M3, M3+ and LL.

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[10] LL is the aggregate composed of all liquid assets not held by financial intermediaries (see Table 1 for a more precise definition).

[11] The results reported in Table 4 are based on data available as of the summer of 1989.

[12] See Crow (1988).

[13] Similar results are obtained when quarterly growth rates are used (see Appendix 2, Table A2.1).

2.2 Intertemporal links

Table 5 shows the intertemporal links between the peaks and troughs of the correlation coefficients of the four-quarter growth rates of various financial aggregates with those of the broad macroeconomic aggregates.[14] The highest correlation coefficient for each aggregate is indicated in bold. A summary of the results is presented in Table 6.

Regardless of how the correlation coefficient is calculated and regardless of what the analysis covers (i.e., price and volume aggregates taken separately or the nominal aggregate), the peak of the M1 correlation coefficient consistently leads those of the other financial and macroeconomic aggregates. Business credit, on the other hand, always lags all other aggregates.

Analysis of the four-quarter (one-quarter) growth-rate correlation coefficients shows that M1 leads real GDP by 2 quarters and that the household credit aggregates (total household credit, total consumer credit and consumer credit extended by chartered banks) lag real GDP by 1 (0) quarter. Most broad monetary aggregates lag real GDP by 4 (3 to 4) quarters. However, they lead the GDP deflator by 1 (2) quarter(s) except M2, which is contemporaneous with the GDP deflator on the basis of the four-quarter correlations. Total business credit lags the GDP deflator by 1 (1) quarter and peaks 9 (9) quarters after M1.

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[14] Similar results were obtained with one-quarter growth rates (see Table A2.2).

Table 4
Four-Quarter Growth Rates of Nominal GDP, Real GDP, the GDP Deflator, and Various Financial Aggregates
Correlation coefficient over various periods

	Nominal GDP				GDP deflator			
	71Q1-89Q1	71Q1-80Q4	81Q1-89Q1	85Q1-89Q1	71Q1-89Q1	71Q1-80Q4	81Q1-89Q1	85Q1-89Q1
Money								
M1	0.38	0.09	0.21	0.39	0.03	-0.26	-0.23	0.70
M2	0.68	0.58	0.37	-0.17	0.80	0.83	0.62	0.27
M2+	0.75	0.71	0.48	-0.05	0.73	0.86	0.45	0.48
M3	0.75	0.71	0.44	0.33	0.73	0.82	0.42	0.75
M3+	0.76	0.73	0.48	0.28	0.68	0.78	0.32	0.74
LL	0.74	0.55	0.60	0.75	0.63	0.77	-0.10	0.79
Total credit								
CC	0.64	0.74	0.40	0.48	0.30	0.48	-0.16	0.64
CMO	0.60	0.69	0.15	0.42	0.29	0.47	-0.40	0.73
CHH	0.63	0.74	0.26	0.44	0.30	0.50	-0.32	0.73
STBC	0.62	0.63	0.41	0.39	0.83	0.86	0.76	0.24
TBC	0.37	0.19	0.42	0.71	0.71	0.62	0.83	0.52
Banks								
CCB	0.65	0.39	0.47	0.72	0.25	-0.10	-0.13	0.68
CMOB	0.08	0.14	-0.46	0.47	0.13	-0.26	0.17	0.66
CHHB	0.39	0.32	-0.18	0.59	0.22	-0.16	0.01	0.71
BL	0.61	0.62	0.39	0.47	0.74	0.64	0.75	0.08
TBCB	0.50	0.61	0.31	0.18	0.70	0.64	0.78	-0.23

(cont'd)

Table 4 (cont'd)
Four-Quarter Growth Rates of Nominal GDP, Real GDP, the GDP Deflator, and Various Financial Aggregates
Correlation coefficient over various periods

	Real GDP[1]			
	71Q1-89Q1	**71Q1-80Q4**	**81Q1-89Q1**	**85Q1-89Q1**
Money				
M1	0.50 [0.55]	0.53 [0.54]	0.41 [0.55]	-0.01 [-0.06]
M2	-0.06 [0.23]	-0.36 [-0.06]	-0.22 [0.26]	-0.44 [-0.51]
M2+	0.14 [0.48]	-0.22 [0.28]	0.04 [0.52]	-0.45 [-0.60]
M3	0.16 [0.38]	-0.15 [0.17]	0.03 [0.39]	-0.14 [-0.31]
M3+	0.21 [0.48]	-0.07 [0.34]	0.16 [0.52]	-0.20 [-0.40]
LL	0.25 [0.56]	-0.31 [0.08]	0.58 [0.74]	0.39 [0.48]
Total credit				
CC	0.53 [0.66]	0.42 [0.71]	0.53 [0.64]	0.14 [0.07]
CMO	0.48 [0.61]	0.34 [0.63]	0.51 [0.58]	-0.09 [-0.06]
CHH	0.52 [0.65]	0.38 [0.68]	0.54 [0.62]	0.02 [-0.03]
STBC	-0.17 [-0.12]	-0.33 [-0.29]	-0.31 [-0.22]	0.34 [0.32]
TBC	-0.38 [-0.31]	-0.64 [-0.47]	-0.36 [-0.21]	0.54 [0.42]
Banks				
CCB	0.60 [0.71]	0.76 [0.74]	0.58 [0.69]	0.44 [0.50]
CMOB	-0.05 [0.01]	0.63 [0.64]	-0.59 [-0.51]	0.11 [0.09]
CHHB	0.28 [0.39]	0.74 [0.73]	-0.18 [0.05]	0.24 [0.24]
BL	-0.07 [0.01]	-0.08 [0.19]	-0.31 [-0.23]	0.57 [0.55]
TBCB	-0.19 [-0.14]	-0.02 [0.24]	-0.42 [-0.38]	0.43 [0.38]

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1. Correlation with financial aggregate in real terms, i.e., divided by the GDP deflator, in [...].

Table 5
Real GDP, GDP Deflator and Nominal GDP
Four-quarter growth correlation coefficients
(1972Q1-1988Q2)

Financial aggregate*	Quarters ahead						Quarters behind		
	Real GDP								
	-4	-3	-2	-1	0	1	2	3	4
M1	0.57	0.73	**0.78**	0.71	0.52	0.25	0.01	-0.13	-0.13
M2	-0.12	-0.07	-0.06	0.03	0.17	0.23	0.37	0.52	**0.62**
M2+	0.07	0.18	0.25	0.35	0.47	0.47	0.49	0.52	**0.54**
M3	-0.07	0.01	0.08	0.21	0.37	0.47	0.54	0.59	**0.60**
CHH	0.22	0.32	0.42	0.55	0.66	**0.68**	0.63	0.55	0.45
CC	0.03	0.17	0.33	0.51	0.67	**0.72**	0.68	0.58	0.48
CCB	0.14	0.27	0.40	0.56	0.70	**0.73**	0.70	0.58	0.48
TBC	-0.63	**-0.70**	-0.69	-0.56	-0.33	-0.13	0.03	0.12	0.12
	GDP deflator								
	-4	-3	-2	-1	0	1	2	3	4
M1	**0.39**	0.32	0.27	0.18	0.09	0.02	-0.05	-0.05	-0.01
M2	0.64	0.71	0.79	0.83	**0.84**	0.79	0.68	0.56	0.43
M2+	0.67	0.71	0.76	**0.77**	0.76	0.69	0.58	0.46	0.35
M3	0.70	0.71	0.74	**0.75**	0.74	0.68	0.58	0.45	0.32
CHH	**0.62**	0.57	0.51	0.42	0.30	0.19	0.06	-0.05	-0.16
CC	**0.62**	0.58	0.52	0.42	0.30	0.18	0.06	-0.05	-0.15
CCB	**0.64**	0.60	0.52	0.42	0.32	0.23	0.15	0.08	0.02
TBC	0.49	0.55	0.61	0.66	**0.69**	**0.69**	0.66	0.60	0.51
	Nominal GDP								
	-4	-3	-2	-1	0	1	2	3	4
M1	0.55	0.63	**0.67**	0.59	0.40	0.17	-0.04	-0.11	-0.04
M2	0.30	0.38	0.47	0.59	0.69	0.72	**0.73**	0.72	0.69
M2+	0.39	0.48	0.57	0.68	**0.76**	**0.76**	0.72	0.68	0.63
M3	0.42	0.48	0.56	0.67	0.77	**0.79**	0.77	0.71	0.62
CHH	0.50	0.54	0.57	0.62	**0.65**	0.60	0.49	0.36	0.24
CC	0.39	0.45	0.52	0.60	**0.65**	0.62	0.52	0.38	0.26
CCB	0.51	0.56	0.60	0.65	**0.68**	0.65	0.57	0.47	0.38
TBC	-0.05	-0.02	0.04	0.17	0.34	0.49	0.58	**0.60**	0.56

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* For real GDP growth, correlation coefficients were calculated using real financial aggregates.

Table 6
Peaks and Troughs of the Correlation Coefficients

Real GDP and the GDP deflator

	Four-quarter growth-rate correlation		One-quarter growth-rate correlation	
Q	**Financial aggregate**	**Macroeconomic goal variable**	**Financial aggregate**	**Macroeconomic goal variable**
0	TBC (T)		TBC (T)	
1	M1 (P)		M1 (P)	
2				Real GDP (P)
3		Real GDP (P)	CHH,CC,CCB (P)	
4	CHH,CC,CCB (P)			
5				
6				
7	M2+,M3 (P)		M2,M2+,M3 (P)	
8	M2 (P)	GDP deflator (P)		GDP deflator (P)
9	TBC (P)		TBC (P)	

Nominal GDP

	Four-quarter growth-rate correlation		One-quarter growth-rate correlation	
Q	**Financial aggregate**	**Macroeconomic goal variable**	**Financial aggregate**	**Macroeconomic goal variable**
0	M1 (P)			
1			M1 (P)	
2	M2+,CHH,CC,CCB (P)	GDP (P)		
3	M3 (P)		M2,M2+,M3,CHH (P)	GDP (P)
4	M2 (P)		CC,CCB (P)	
5	TBC (P)		TBC (P)	

Q = Quarter
P = Peak
T = Trough

The correlations with nominal GDP show a similar pattern. The main difference is the shorter time span between the peak in M1 and the peak in total business credit. M1 leads nominal GDP by 2 (2) quarters. For the broad monetary aggregates and household credit aggregates, however, things are not so cut and dried. The correlation coefficients calculated for four-quarter growth rates indicate that M2+ and the household credit aggregates (total credit and consumer credit) are contemporaneous with nominal GDP and that M3 and M2 lag nominal GDP by 1 and 2 quarters, respectively. On the other hand, one-quarter growth-rate correlations show that all the broad monetary aggregates are contemporaneous with nominal GDP and that consumer credit aggregates lag nominal GDP by one quarter. Lastly, total business credit lags nominal GDP by 3 (2) quarters.

This review of the temporal links between the financial and macroeconomic aggregates clearly shows that different financial aggregates should serve as a contemporaneous or leading indicator for the various goal variables (nominal GDP, real GDP and the GDP deflator). Care must be exercised in using them for monetary policy purposes, however.

3. Estimation of Indicator Models

The indicator-model estimation results reported in this paper relate the quarterly growth rate of a goal variable[15] to the lagged growth rate of that variable, to contemporaneous and/or lagged growth in one or more financial aggregates, and to contemporaneous and/or lagged growth in other financial variables.[16,17] Since complete quarterly financial data are, in most cases, released shortly after the end of a quarter t, models employing only lagged variables may be used to forecast the goal variable's growth rate for quarters t and t+1 within two weeks of the end of quarter t, while models using contemporaneous variables can be used to predict the growth of the goal variable in quarter t within one or two weeks after the quarter's end - close to 50 days before the national accounts are released.

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[15] The concept of a "goal" variable simply refers to a variable that is of interest to economic agents.

[16] Some of the indicator models used in our study are described in more detail in two technical reports published by the Bank of Canada (Hostland, Poloz and Storer, 1988 and Milton, 1988). Other models were developed later at the Bank of Canada by Crawford (final demand component models), Hostland (composite models employing the forecasts of several models) and Laver (models using bank credit data and changes in the growth rates of selected credit aggregates). The astructural approach adopted by these authors is similar to that taken by, for example, Barnett and Spindt (1979, 1980) and Driscoll, Ford and Mullineux (1985).

[17] The only explanatory variables in the indicator models presented in this study are financial. The first non-financial data available after the end of a quarter are employment data, which are generally released at the end of the first complete week following the quarter, and consumer price index data, which are released at the end of the second week. The usefulness of the information provided by these non-financial variables will be the subject of another study as part of our ongoing research into economic monitoring models incorporating other sources of information.

The basic structure of each of these models is given by equation (1) for simple bivariate models that use a single financial aggregate as an explanatory variable, and by equation (2) for multivariate models that use either several financial aggregates or one financial aggregate plus one or more additional financial variables:

$$\text{goal} = \alpha + \beta^{p}(L)\text{goal} + \delta^{q}(L)FA_{i} + \mu \qquad (1)$$

$$\begin{aligned}\text{goal} = \alpha + \beta^{p}(L)\text{goal} + \delta^{q}(L)FA_{i} + \sigma^{r}(L)FA_{j} \\ + \pi^{s}(L)OFV + \mu \qquad (2)\end{aligned}$$

where "goal" is the variable of interest, FA_i is financial aggregate i, FA_j is financial aggregate j and OFV represents other financial variables. β^p, δ^q, σ^r and π^s are polynomials in the lag operator L of order p, q, r and s, respectively. All variables are expressed in quarterly growth rates.

For the purposes of this study, the goal variables are: nominal GDP, real GDP, the GDP deflator, the fixed-weight GDP deflator, the consumer price index (CPI), household expenditures (value, volume and deflator), housing expenditures (value, volume and deflator), business fixed investment expenditures (value, volume and deflator) and private final demand in value terms (i.e., total household, housing and business fixed investment expenditures).

The financial aggregates used in the indicator models are M1, M2, M2+, M3, consumer credit (total (CC) and that extended by banks (CCB)), short-term business credit (total (STBC) and that extended by banks (STBCB)), bank loans to businesses (BL) and bank loans to businesses plus bankers' acceptances (BLBA).[18] In the case of models of macroeconomic aggregates in constant dollars, the financial aggregates are deflated by the consumer price index.[19,20]

Summary Table 7 shows that, in the models examined in the present study, developments in nominal macroeconomic aggregates are mostly explained by developments in monetary aggregates. Household credit also occasionally shows up as an explanatory variable. Virtually all financial aggregates serve to predict developments in real macroeconomic aggregates. Lastly, the broad monetary aggregates are most closely linked to the various price indices. Only the traditional additive-type financial aggregates are used in this study since previous research has demonstrated that their explanatory power is generally better than Divisia-type aggregates.[21]

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[18] A number of studies on the relationship between real GDP growth and credit aggregate growth have shown that, in certain cases, changes in the growth rate of these credit aggregates contain information (see, for example, Freedman and Longworth, 1990), and indicator models including the second derivative of certain credit aggregates as explanatory variables have been developed for the period 1972Q1-1989Q2. These models either add lagged changes in the growth rate of bank consumer credit to the basic model employing only real lagged M1 values, or add contemporaneous and lagged values of the change in the growth rate of bank consumer credit and business short-term credit to the model using contemporaneous and lagged M1 values in real terms. However, because these additional variables are statistically not significant in the 1970s and early 1980s (Table A3.4), these models are not included among the models examined in this study.

[19] Because the consumer price index is the only index of final prices that is available shortly after the end of a quarter, it is a natural choice for a financial aggregate deflator. Moreover, when indicator models estimated using financial aggregates deflated by the GDP price deflator are compared with models using financial aggregates deflated by the consumer price index, the latter generally outperform the former.

[20] The names of the aggregates in real terms listed in Table 7 are the same as those of the aggregates in nominal terms with the addition of an "R" at the end.

The other financial variables used in the indicator models are: the interest rate on prime 90-day commercial paper (R90), the Toronto Stock Exchange closing price on the last day of the month (TSE) and an index of the average resale price for homes (PMLS). A sizable body of previous research has shown that, out of the many possible financial variables, only this subset contains additional information.[22]

In numerous studies, the Bank of Canada has used the following approach to derive the estimated final form for each of the indicator models. First, the optimum number of lags on the endogenous variable is established using Akaike's (1969) final prediction error (FPE).[23] In most cases, one or two lags are sufficient to capture all the information contained in the lagged values of the series. The optimum number of lags for each of the financial aggregates and for the other financial variables are then determined by the same criterion.[24] Since in several cases there are a number of competing models that explain the same macroeconomic aggregate, the models were compared using Hendry and Richard's (1982) "encompassing" principle, and only the "best" models are reported in this study.

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[21] See, for example, Hostland, Poloz and Storer (1988).

[22] Ibid.

[23] The final prediction error is defined as follows:

$$FPE = \{(n+p)/n^*(n-p)\}^*SSR \quad (3)$$

where n is the number of observations, p the number of estimated parameters and SSR the sum of squared residuals.

[24] In some cases, the sum of the estimated coefficients of the lags of the credit aggregate's growth rate is not statistically different from zero. The estimation results reported in this study impose the constraint that the sum of the coefficients is equal to zero in such circumstances.

Table 7
Financial Aggregates Used in Indicator Models

	Indicator variable								
	M1	**M2**	**M2+**	**M3**	**CC**	**CMO**	**CHH**	**CCB**	**STBC**
Goal variable									
Y	*	[*]				*[*]	*		
C$			*[*]					*	
I$	*[*]								
H$	*[*]								
DD$	[*]		*						
Variables in constant dollars									
Q					[*]	*	[*]		*
C									
I		[*]							
H									
Deflators									
P		*		[*]			*		[*]
FWP		*							
CPI		*[*]							
PC		*							
PI			*						[*]
PH	*[*]								

Note: Refer to Appendix 1 for definitions of variables. (cont'd)

* Model without contemporaneous financial aggregate
[*] Model with contemporaneous financial aggregate

Table 7 (cont'd)
Financial Aggregates Used in Indicator Models

	Indicator variable							
	STBCB	BL	BLBA	M1R	M2R	CCBR	CHHR	CMOR
Goal variable								
Y								
C$								
I$								
H$								
DD$								
Variables in constant dollars								
Q				*		[*]		
C				*			[*]	
I	*		[*]					
H				[*]	*			[*]
Deflators								
P		[*]						
FWP								
CPI								
PC								
PI								
PH								

Note: Refer to Appendix 1 for definitions of variables.

*	Model without contemporaneous financial aggregate
[*]	Model with contemporaneous financial aggregate

November 1989 national accounts data and financial data released in February 1990 were used to estimate the various models.[25] All data were seasonally adjusted, with the exception of the additional financial variables (R90, TSE and PMLS). The main reason seasonally adjusted data were used exclusively in the study is that the analysis and monitoring of economic developments naturally tends to focus on pre-filtered data. In order to determine the effect of this filtering on the relationships described in our study, the models that performed best according to the criteria laid out in the following section will be re-estimated with raw data at the end of that section.

The structure of each model (i.e., its particular set of explanatory variables and the number of lags for each variable) and their labels[26] are given in Table 8, and the contribution of financial variables (aggregates and other financial variables) to the explanatory power of each of the models relative to a simple autoregressive model is shown in Table 9. The complete estimation results for the 1972Q1-1989Q2 period are reported in Appendix 3; Table A3.1 covers the simple autoregressive models and Tables A3.2 and A3.3 show the full-fledged indicator models.

Most of the estimated models explain between 0.3 and 0.7 of the variance in the growth rate of the macroeconomic goal variable. Price-index indicator models exhibit the highest explanatory power, generally in the range of 0.6 to 0.8. Nominal macroeconomic models were a bit weaker, generally falling between 0.4 and 0.5. Lastly, the real macroeconomic models were the least powerful, falling between 0.2 and 0.4 in most cases. The results shown in Table 9 indicate that adding financial variables to the simple autoregressive models reduced the sum of the squared estimation residuals by 45 per cent at the most, with gains usually falling in the 20 to 30 per cent range.

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[25] Because this study used the most recent data available at the time of writing, the results may differ slightly from the those reported in some earlier studies (Hostland, Poloz and Storer, 1988, Milton, 1988, and Muller, 1989). In a very small number of cases, one or other of the additional financial variables loses its statistical significance. Nevertheless, estimation results are reported "as is," since the development and estimation of new models would be far beyond the scope of the present study.

[26] The first letter of the labels for the various indicator models employing only lagged values of financial variables indicates whether the model is based on a monetary (M) or credit (C) aggregate. The last letter of the labels for the models of the large macroeconomic aggregates serves to distinguish between those based on nominal aggregates (Y), volume (Q) and price (P). Indicator models also using contemporaneous financial aggregate values have the same labels as the first set of models with a "B" added in front.

Adding contemporaneous values of the growth of a financial aggregate often dramatically improved the explanatory power of the indicator models. In certain cases, however, the explanatory power deteriorated as a result. This occurred when models using only lagged values or contemporaneous values were developed independently. At the moment they are not nested, but it is hoped that this will be rectified in future work.

Because indicator models are astructural by nature or can be seen as imposing a series of restrictions on larger structural models, they are particularly vulnerable to the Lucas critique. If these models are to be useful, economic policy-makers must be confident of their properties and stability. One of the important steps in the acceptance of these models, therefore, is a series of stability tests designed to determine whether the estimated parameters are invariant over time, regardless of changes in economic policy.

Stability tests were performed for three key years - 1976, 1979 and 1982. These dates correspond more or less to shifts in Canadian monetary policy (1976 and 1982) and in U.S. monetary policy (1979). The results of Chow tests (shown in Table 10) indicate that, in general, the stability hypothesis cannot be rejected. Stability is rejected systematically only in the case of the nominal GDP models based on credit aggregates and the model of the housing expenditures deflator. The models using M1 show no sign of instability, despite the many innovations affecting the demand for this aggregate.

Table 8
Structure of Estimated Indicator Models
(All variables expressed in quarterly growth rates)

Models without contemporaneous financial aggregates

	Model	Financial aggregate	Other variables	R^2 of estimated model
GDP				
Current dollars	MBY	M1 (-1,-2)	-	0.52
	MMY	M1 (-1,-2)	R90 (-1 to -5),TSE (-1)	0.64
	C1Y	CMO (-1)	TSE (-1),PMLS (-1)	0.49
	C2Y	CHH (-1)	TSE (-1)	0.44
Constant dollars	MBQ	M1R (-1,-2)	-	0.37
	MMQ	M1R (-1 to -5)	TSE (-1)	0.46
	C1Q	CMO (-1,-2)	TSE (-1)	0.22
	C2Q	TBC (-1,-2)	TSE (-1)	0.27
Deflator	MBP	M2 (-1,-2)	-	0.66
	MMP	M2 (-1,-2)	R90 (-1), TSE (-1)	0.67
	C1P	CCB (-1)	-	0.62
	C2P	CCB (-1)	PMLS (-1)	0.62
Fixed-weight GDP deflator	MFW	M2 (-1,-2)	-	0.67
CPI	MCPI	M2 (-1,-2)	-	0.78
Household expenditures				
Current dollars	MC$	M2P (-1), CCB (-1 to -5)*	-	0.37
Constant dollars	MC	M1R (-1 to -5)	TSE (-1 to -5)	0.43
Deflator	MPC	M2 (-1,-2)	-	0.78
Business fixed investment				
Current dollars	MI$	M1 (-1,-2)	-	0.34
Constant dollars	MI	STBCB (-1,-2)	-	0.76
Deflator	MPI	M2P (-1)	-	0.65
Housing				
Current dollars	MH$	M1 (-1,-2)	-	0.40
Constant dollars	MH	M2R (-1 to -6)*	TSE (-1 to -3)	0.41
Deflator	MPH	M1 (-2)	-	0.34
Private domestic demand				
Current dollars	MDD$	M2P (-1)	TSE (-1)	0.40

(cont'd)

Table 8 (cont'd)
Structure of Estimated Indicator Models
(All variables expressed in quarterly growth rates)

Models with contemporaneous financial aggregates

	Model	Financial aggregate	Other variables	R^2 of estimated model
GDP				
Current dollars	BMBY	M1 (-1,-2),M2 (0)	-	0.66
	BMMY	M1 (-1,-2),M2 (0)	TSE (-1)	0.68
	BC1Y	CMO (0)	-	0.42
	BC2Y	CHH (0)	-	0.42
Constant dollars	BMBQ	M1R (-1,-2), CCBR (0)	-	0.42
	BMMQ	M1R (-1,-2), CCBR (0)	R90 (-1),TSE (-1)	0.45
	BC1Q	CHH (0 to -3)	-	0.37
	BC2Q	CC (0 to -3)	-	0.36
Deflator	BMBP	M2 (-1,-2),M3 (0)	-	0.70
	BMMP	M2 (-1,-2),M3 (0)	R90 (-1),TSE (-1)	0.71
	BC1P	BL (0)	-	0.63
	BC2P	STBC (0)	-	0.63
Household expenditures				
Current dollars	BMC$	M2P (0)	-	0.35
Constant dollars	BMC	CHHR (0 to -2)	-	0.32
Deflator	BMPC	M2 (0 to -2)	-	0.78
Business fixed investment				
Current dollars	BMI$	M1 (0 to -2)	-	0.34
Constant dollars	BMI	BLBA (0 to 3)*, M2(0)	TSE (0 to -3)	0.42
Deflator	BMPI	STBC (0,-1)*	TSE (0)	0.60
Housing				
Current dollars	BMH$	M1 (0 to -2)	-	0.46
Constant dollars	BMH	M1R (0 to -5), CMOR (0 to 5)*	-	0.57
Deflator	BMPH	M1 (0 to -2)	TSE (0 to -7)	0.54
Private domestic demand				
Current dollars	BMDD$	M1 (0 to -2)	TSE (0)	0.48

* constraint imposed that sum of coefficients = 0

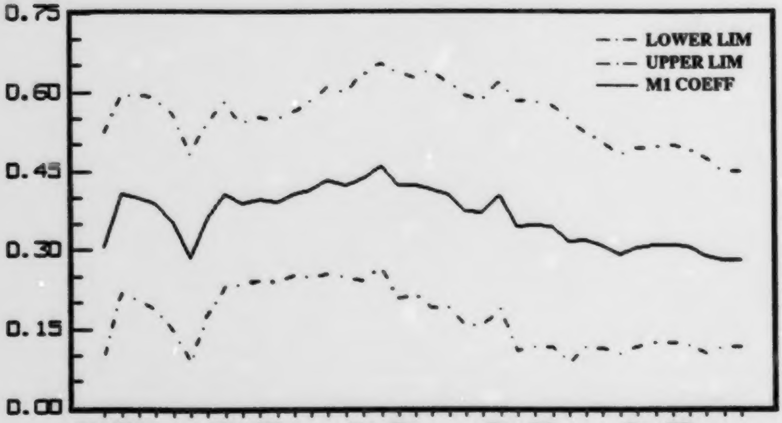
Table 9
Univariate Versus Multivariate Models
Ratio of sum of squared residuals from multivariate-model estimations to sum of squared residuals from univariate-model estimations

Dependent variable	Models without contemporaneous financial aggregates				Models with contemporaneous financial aggregates			
Y	MBY	73.2	MMY	55.0	BMBY	51.7	BMMY	49.3
	C1Y	78.9	C2Y	82.7	BC1Y	88.7	BC2Y	89.6
Q	MBQ	71.0	MMQ	60.4	BMBQ	65.4	BMMQ	61.0
	C1Q	82.3	C2Q	76.7	BC1Q	70.4	BC2Q	72.0
P	MBP	84.0	MMP	81.6	BMBP	73.3	BMMP	72.3
	C1P	94.4	C2P	92.5	BC1P	91.2	BC2P	90.2
FWP	MFW	92.0						
CPI	MCPI	71.3						
C$	MC$	77.8			BMC$	80.0		
C	MC	61.5			BMC	73.0		
PC	MPC	63.5			BMPC	63.5		
I$	MI$	91.6			BMI$	91.2		
I	MI	90.3			BMI	70.4		
PI	MPI	82.5			BMPI	93.6		
H$	MH$	87.3			BMH$	78.5		
H	MH	77.7			BMH	56.9		
PH	MPH	93.2			BMPH	64.9		
DD$	MDD$	81.0			BMDD$	70.0		

In the case of the models using M1 - the models most likely to show signs of instability - we examined the evolution, over time, of the sum of the estimated coefficients of the two lags of real M1. Rolling estimations with a fixed span of 30 observations were carried out with the initial sample covering the 1971Q1-1980Q1 period and the last the 1981Q2-1989Q2 period. The sum of the estimated coefficients varies relatively little over time (Figure 6) and is never outside the 95 per cent confidence interval of any estimation period.

Figure 6

Sum of Estimated M1 Coefficients and 95 Per Cent Confidence Band (MBQ model)



Rolling Regression Coefficient (Estimate based on sample of 30 observations ending at the quarter for which the coefficient is shown.)

Table 10
Stability of Indicator Models: Results of Chow Test[1]

	Models without contemporaneous financial aggregates			Models with contemporaneous financial aggregates		
Model[2]	76/77	78/80	82/83	76/77	79/89	82/89
MBY	1.84	1.42	3.07	3.16	2.49	2.35
MMY	1.49	2.02	1.71	1.39	1.18	1.06
MBQ	0.71	1.23	1.33	0.75	0.92	1.40
MMQ	0.99	1.02	0.95	0.76	0.60	1.06
MBP	2.31	0.97	1.24	3.52*	1.75	0.77
MMP	2.93	3.98*	1.45	2.87	3.04*	0.70
C1Y	5.27*	5.05*	4.73*	6.35*	4.08*	2.85
C2Y	4.06*	3.74*	2.59	3.95	3.70	3.86
C1Q	1.51	1.39	2.60	1.17	1.08	1.47
C2Q	2.10	2.71	0.86	1.67	1.95	1.96
C1P	0.61	0.65	1.78	0.45	1.08	1.61
C2P	5.45*	4.92*	4.98*	1.05	1.65	1.75
MC$	2.11	0.68	0.59	3.48*	0.41	1.35
MPC	2.45	4.25*	14.20*	2.34	1.80	2.24
MC	1.70	0.65	0.85	2.80	0.50	1.74
MI$	0.41	0.91	0.19	0.48	0.48	0.19
MPI	1.44	0.97	4.22*	2.09	3.77	7.84*
MI	0.71	0.81	0.16	2.17	1.15	1.27
MH$	0.58	0.84	1.37	0.82	1.96	5.25*
MPH	2.31	1.74	0.65	2.66	1.82	0.31
MH	0.37	2.22	0.75	0.99	0.80	0.79
MDD$	1.15	0.46	0.10	1.19	1.05	0.64
MFW	2.15	0.69	0.98			
MCPI	2.00	1.85	2.67			

1. Tests of instability between the following periods: (i) 1972Q1-1976Q4 and 1977Q1-1989Q2; (ii) 1972Q1-1979Q4 and 1980Q1-1989Q2; and (iii) 1972Q1-1982Q4 and 1983Q1-1989Q2.

2. Refer to Table 8 for the exact structure of each of the models.

* indicates hypothesis of no instability rejected at 1 per cent

Another way to gauge the uncertainty surrounding the true structure of these models is to compare the regression standard deviation of the model estimated over the 1972Q1-1979Q4 period to the standard deviation of the forecasting error of these models outside the estimation period.[27] Excessive data mining will result in forecasting performances that deteriorate very quickly. The results reported in Table 11 indicate that, in general, the regression standard deviation of the indicator models for 1972Q1-1979Q4 does not differ greatly from the standard deviation of the forecasting error of these models for 1985Q1-1989Q2. Only three models (real housing expenditures (BMH), the deflator of fixed investment expenditures (BMPI) and private final demand (BMD$)), all of which use contemporaneous values of financial aggregates, show signs of significantly poorer performance than might be expected on the basis of the estimated standard deviation.

One may conclude, therefore, that aside from certain isolated cases, the estimates of the indicator models are stable despite the many financial innovations that have influenced the various financial aggregates in the late 1970s and early 1980s.

4. Evaluation of Indicator-Model Projections

In order to assess the reliability of indicator models as sources of information, their predictive performance during the 1980s is examined next.

The following procedure was used to reproduce as closely as possible the conditions under which these models might have been used during the 1980s. For each quarter t, from the first quarter of 1979 to the second quarter of 1989, the models were estimated as far as quarter t-1. The models specific to quarter t were then used to predict the growth of the goal variable

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[27] Stockton and Struckmeyer (1989) suggest using such a comparison to "measure" the effect on forecasting errors of uncertainty about the true structure of the model.

Table 11
Standard Deviation of Estimations and Forecasts

Model	Standard deviation[1] of estimation	Standard deviation[2] of forecast	Ratio[3]
MBY	0.94	0.71	0.76
MMY	0.74	0.70	0.94
MBQ	0.82	0.59	0.72
MMQ	0.81	0.64	0.78
MBP	0.71	0.45	0.63
MMP	0.57	1.03	1.80
C1Y	0.84	1.14	1.36
C2Y	0.95	0.92	0.97
C1Q	0.85	0.82	0.96
C2Q	0.77	0.79	1.03
C1P	0.75	0.38	0.51
C2P	0.60	0.86	1.08
MC$	0.94	0.58	0.62
MPC	0.33	0.39	1.18
MC	1.00	0.81	1.23
MH$	3.14	3.39	1.08
MPH	1.91	1.43	0.75
MH	3.38	3.17	0.94
MI$	3.09	2.62	0.85
MPI	0.61	1.02	1.67
MI	2.81	2.51	0.89
MDD$	1.22	0.49	0.40
MPF	0.71	0.33	0.46
MCPI	0.39	0.35	0.90

(cont'd)

1. Standard deviation of model estimated over the 1972Q1-1979Q4 period.
2. Standard deviation of forecast error for the 1985Q1-1989Q2 period from model estimated over 1972Q1-1979Q4.
3. Ratio of standard deviation of forecast error to standard deviation of estimation.

Table 11 (cont'd)
Standard Deviation of Estimations and Forecasts

Model	Standard deviation[1] of estimation	Standard deviation[2] of forecast	Ratio[3]
BMBY	0.70	0.71	1.01
BMMY	0.65	0.79	0.65
BMBQ	0.81	0.53	0.65
BMMQ	0.81	0.61	0.75
BMBP	0.62	0.46	0.74
BMMP	0.55	0.87	1.58
BC1Y	0.99	0.84	0.85
BC2Y	1.00	0.73	0.73
BC1Q	0.87	0.63	0.72
BC2Q	0.85	0.66	0.78
BC1P	0.73	0.48	0.66
BC2P	0.70	0.43	0.61
BMC$	0.90	0.63	0.70
BMPC	0.37	0.39	1.05
BMC	0.99	0.58	0.59
BMH$	2.91	3.49	1.20
BMPH	1.63	23.92	14.67
BMH	3.02	3.02	1.00
BMI$	3.16	2.61	0.83
BMPI	0.60	1.07	1.78
BMI	2.53	46.35	18.32
BMDD$	1.22	12.47	10.22

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1. Standard deviation of model estimated over the 1972Q1-1979Q4 period.
2. Standard deviation of forecast error for the 1985Q1-1989Q2 period from model estimated over 1972Q1-1979Q4.
3. Ratio of standard deviation of forecast error to standard deviation of estimation.

in quarter t (and quarter t+1 for models using lagged values exclusively).[28] These projections would have been made at the beginning of quarter t+1 since historical data to quarter t-1 would have been released at the end of quarter t and financial data to quarter t would have been released early in quarter t+1. This procedure makes it possible to obtain an estimate of the growth of the goal variable in quarter t about 60 days before the release of national accounts data. These forecasts are referred to as *current-quarter* forecasts in subsequent analysis. Forecasts for quarter t+1 are referred to as *one-quarter-ahead* forecasts.

The indicator models described in the previous section cover nominal and real macroeconomic aggregates and their associated deflators. In order to determine whether it would be best to use the indicator-model forecast of the growth in the nominal macroeconomic aggregate or, instead, the forecast implied by the volume and price growth-rate forecasts of the individual indicator models, the various forecasts of real GDP and GDP deflator growth rates were combined and evaluated against indicator-model forecasts.[29] The implicit forecasts of the growth of the various demand components, as well as that of private final demand growth, were also evaluated.[30]

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[28] In actual fact, this method only approximates the historical conditions under which the models might have been used, since the entire analysis is based on data available as of February 1990. These data, particularly national accounts data, have been extensively revised since they were first released. Consequently, it could be argued that, to the extent that we are supplying more information to the models than actually was available at the time of their hypothetical use, our assessment is biased in their favour. This possible bias is examined in more detail in Section 6, where the forecasts of certain models based on the data actually available at the time the forecasts would have been made are compared with the first release of the national accounts by Statistics Canada.

[29] Altogether, there were 18 implicit forecasts of nominal GDP. Sixteen were produced by various combinations of real GDP and GDP deflator forecasts and two stemmed from earlier work on combining direct forecasts of the nominal GDP growth rate. The labels and structure of each of these implicit models are listed in Table A4.3 in Appendix 4.

[30] Thus far, only nominal final demand indicator models have been developed. It is possible to use the forecasts of private final demand components in real terms and the forecasts of their deflators to construct a forecast of final demand in real terms and its associated deflator.

Since there is no single definitive way to assess forecasts,[31] a number of criteria were used in this study.[32] First, it is preferable for the forecasts (XP) of a variable (X) to be strongly correlated with that variable. This makes the correlation coefficient (ρ) between the two the natural choice as an evaluation criterion. It is also desirable to minimize the forecasting error. That is why measurements of the mean forecasting error (ME), the mean absolute error (MAE) and the root-mean-squared error (RMSE) are reported, as well as the largest forecasting error over the 1980Q1-1989Q2 period. Other measures used include:

(i) the ratio of the variance of the forecasting error to the variance of the series X, which is zero when XP is a perfect forecast of X (Granger and Newbold, 1977);[33]

and

(ii) the decomposition of the mean square of error in terms of bias (UM), variance (UR) and correlation (UD). Optimal forecasts will produce values for UM and UR that are not significantly different from zero and UD should be close to one.[34]

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31. See, for example, Mahmoud (1984) for a review of the various criteria used in the economic literature.

32. For more detail on these criteria, see Table A4.1 in Appendix 4.

33. The mean error must be equal to zero and the forecasting error series must not be correlated with the predicted series (XP).

34. $UM = ((XP/n)-(X/n))/D^2_N$; $UR = (s_{XP}-r^*s_X)^2/D^2_N$; $UD = (1-r^2)^*s^2_X/D^2_N$ and UM + UR + UD = 1, where XP = predicted series, X = historical series, n = number of observations, s_i = standard deviation of series i, r = correlation coefficient between the predicted and historical series, and $D^2_N = (1/n)^* \Sigma\, (X-XP)^2$. (See Granger and Newbold, 1977, p. 286.) The requirement that UM and UR be close to zero is equivalent to requiring that α and β are not different from 1 and 0, respectively, in equation (4), which relates the predicted and historical series.

Another way to verify the absence of bias and the efficiency of forecasts is to estimate the following equation, which relates the historical series to its forecast:

$$X = \alpha + \beta \, XP + \mu \, . \qquad (4)$$

An optimal forecast should yield estimates of α and β that are not statistically different from zero and one, respectively. To ensure that forecast errors are not correlated over time, the Ljung-Box-Pierce Q-statistic was calculated for 2, 4, 6, and 8 lags.

The effect of certain macroeconomic shocks was also examined using regressions relating the historical series to its predicted value and additional variables. These variables included changes in inventories, in the trade balance and in oil prices, in nominal or real terms (depending on the nature of the historical series) and, in the case of price aggregates, the changes in the implicit deflators of inventories and the trade balance.

The power of various models to predict the direction of change in the growth rate of the goal variable, either up or down, was also examined. This more qualitative analysis was made for all changes in growth rates of the goal variable, as well as for those exceeding the standard deviation of the change in the growth rate of the goal variable during the 1970s.

Lastly, the number of correctly predicted turning points is given (the number of times that the model correctly predicted that the growth rate of the goal variable would change sign), and the number of false signals (that is, the number of times the model erroneously predicted a change of sign in the growth rate of the goal variable).[35]

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[35] Table A4.2 in Appendix 4 gives, for each goal variable, the actual number of changes in the growth rate exceeding the standard deviation of the change in the growth rate during the 1970s and the number of turning points during the 1980s.

Table 12 presents selected evaluation statistics for the best models; a complete set of evaluation statistics can be found in Appendix 4. Tables A4.4 through A4.7 concern the evaluation of nominal GDP forecasts for the current quarter (Table A4.4), the quarter ahead (Table A4.5), the combined period of the current quarter and the quarter ahead (Table A4.6), and GDP forecasts for the current quarter based on models employing contemporaneous values of financial aggregates (Table A4.7). Evaluation statistics of forecasts for real GDP, price indices and GDP components are presented in Tables A4.8 through A4.11.

Several general conclusions may be drawn from this detailed evaluation of the various forecasts. First, the models' forecasts of developments in the large macroeconomic aggregates, such as GDP and private final demand, are better than those for the demand components. Of the three types of macroeconomic aggregates (nominal, real and price index), forecasts of the growth in prices are generally the best in terms of correlation with the historical series.

These are followed by forecasts of movements in nominal macroeconomic aggregates. Forecasts of movements in real macroeconomic aggregates are generally the least satisfactory. Combining forecasts of growth in real terms and in terms of prices does not always produce better forecasts of growth in the nominal aggregate.

In the case of private final demand, household expenditures and housing expenditures, the forecasts obtained directly from the model of the nominal macroeconomic aggregate are better than those obtained by combining volume and price forecasts. Most of the forecasts for the major aggregates are not biased and are efficient, in the sense that the estimated values of α and β are not different from 0 and 1, respectively. On the other hand, demand-component forecasts are generally biased, with the exception

Table 12
Comparison of the Properties of Forecasts from the Autoregressive Models and the Best Indicator Models for the Current Quarter and the Quarter Ahead (1980Q1-1989Q2)

	Current quarter						
	Autoregressive model			**Indicator model**			
Goal variable	**∫**	**ME**	**RMSE**	**Model**	**∫**	**ME**	**RMSE**
Y	0.57	-0.45	0.91	**MI1Y***	0.74	-0.14	0.67
P	0.82	-0.25	0.50	**C1P**	0.83	-0.12	0.44
Q	0.36	-0.16	0.95	**MBQ**	0.68	-0.03	0.74
PFW	0.78	-0.29	0.50	**MPF**	0.83	-0.16	0.41
CPI	0.86	-0.18	0.46	**MCPI**	0.88	-0.01	0.38
C$	0.24	-0.49	0.91	**MC$**	0.18	-0.16	0.87
PC	0.85	-0.16	0.44	**MPC**	0.86	-0.01	0.39
C	-0.04	-0.16	0.89	**MC**	0.45	0.09	0.88
I$	0.40	-0.63	3.03	**I*PI***	0.57	-0.13	2.62
PI	0.52	-0.26	0.97	**MPI**	0.59	-0.07	0.86
I	0.45	-0.10	2.96	**MI**	0.55	-0.05	2.77
H$	0.44	-0.06	5.05	**H*PH***	0.48	1.10	13.40
PH	0.39	-0.38	1.06	**MPH**	0.20	0.06	1.28
H	0.39	0.60	4.62	**MH**	0.45	0.50	4.46
DD$	0.43	-0.45	1.11	**MDD$**	0.53	-0.17	0.97
DD	-	-	-	**DD***	0.57	0.08	2.06
PDD	-	-	-	**PDD***	0.88	-0.04	0.71
P-BIS	0.82	-0.25	0.50	**MBP**	0.86	-0.14	0.42

(cont'd)

Table 12 (cont'd)
Comparison of the Properties of Forecasts from the Autoregressive Models and the Best Indicator Models for the Current Quarter and the Quarter Ahead (1980Q1-1989Q2)

	Quarter ahead						
	Autoregressive model			Indicator model			
Goal variable	ʃ	ME	RMSE	Model	ʃ	ME	RMSE
Y	0.21	-0.69	1.18	MI1Y*	0.68	-0.18	0.72
P	0.76	-0.33	0.60	C1P	0.78	-0.16	0.50
Q	-0.21	-0.17	1.05	MBQ	0.67	-0.03	0.74
PFW	0.72	-0.46	0.65	MPF	0.81	-0.21	0.45
CPI	0.78	-0.30	0.61	MCPI	0.85	-0.03	0.42
C$	0.24	-0.62	0.98	MC$	0.23	0.03	0.95
PC	0.77	-0.27	0.56	MPC	0.82	0.00	0.44
C	-0.37	-0.17	0.91	MC	0.48	0.02	0.84
I$	0.20	-0.90	3.35	I*PI*	0.39	-0.29	2.37
PI	0.53	-0.53	1.04	MPI	0.58	-0.18	0.88
I	0.23	-0.08	3.23	MI	0.38	-0.11	3.07
H$	0.25	-0.10	5.34	H*PH*	0.40	1.55	5.17
PH	0.09	-0.50	1.21	MPH	0.06	-0.04	1.38
H	0.14	0.86	5.09	MH	0.26	0.68	4.86
DD$	0.05	-0.65	1.32	MDD$	0.53	-0.01	0.96
DD	-	-	-	DD*	0.61	-0.04	1.00
PDD	-	-	-	PDD*	0.81	-0.06	0.43
P-BIS	0.75	-0.33	0.60	MBP	0.83	-0.19	0.46

ʃ = correlation coefficient
ME = mean forecast error
RMSE = root-mean-square error
* = forecast based on forecasts for price and volume components

of the deflator for housing expenditures, business fixed investment (real terms) and the deflator for these expenditures.

The results also show that, on the basis of the correlation coefficient between the historical series and the forecast, the models that do not include any contemporaneous values of financial aggregates perform better than the models that do. Of all the models, only those for household and housing expenditures, in current and constant dollars, provide better forecasts when they use contemporaneous financial aggregate values. Generally speaking, however, there is no need to use both types of model, since the models used to predict developments in the goal variable during the current quarter and the quarter ahead do an adequate job.

The best forecasts of nominal GDP growth are always those combining forecasts of real GDP growth produced by models based on the monetary aggregate M1 (in real terms) with forecasts of the growth of the GDP deflator produced by models based on bank consumer credit (models MI1Y through MI4Y). This remains true no matter what the forecast horizon and the type of forecast model (with or without contemporaneous financial aggregates). Among the latter, the preferred model is the MI1Y model, which combines forecasts of real GDP growth based on the simple indicator model including only M1 in real terms (model MBQ) with price forecasts generated by the bank consumer credit indicator model (model C1P), even though the performance of the MI1Y model (correlations, mean error, etc.) is sometimes marginally poorer than the model using price forecasts based on bank consumer credit and the average resale price of homes[36] (model MI2Y). The edge enjoyed by the MI1Y model stems from the fact that it uses volume and price forecasts that are among the best in their category and that the underlying volume and price indicator models are stable.

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[36] This last model is unstable; see Section 3.

Among the four real GDP indicator models, those based on M1 in real terms (models MBQ and MMQ) generate forecasts that are consistently[37] and significantly better than those of models employing credit aggregates (models C1Q and C2Q). In addition, according to all evaluation criteria, the simple monetary model (MBQ) outperforms the monetary model employing additional financial variables (MMQ).

With respect to the GDP deflator models, the best are those based solely on M2 (MBP) or on bank household credit (C1P). The former has a slight edge over the latter in terms of most evaluation criteria (correlation, mean error, etc.) The forecasts of the two models are not biased. Since the combination of the second model's (C1P) forecasts with those of GDP in volume terms produces better forecasts for nominal GDP, the C1P model emerges as the best indicator model of the GDP deflator. The forecasts of the MBP model are also worth monitoring closely. The best forecasts of the other major price indices (fixed-weight GDP deflator and consumer price index) are provided by the simple M2-based indicator models. These two models yield excellent price forecasts no matter what criteria are used.

The forecasts for the total demand components are generally less satisfactory (systematic bias, slope coefficient β significantly below 1, large errors, etc.). The only exceptions are forecasts for final demand and household expenditure deflators, which are quite good (strong correlation with historical series, no bias, slope coefficient β equal to 1, etc.). Some other forecasts are also unbiased (business fixed investment expenditures in value terms (I*PI*) and in real terms (I), private domestic demand in value terms (DD$) and in real terms (DD)), but their correlation with the historical series is much weaker, generally around 0.6. Lastly, forecasts for household expenditures in value and real terms, as well as those for all housing expenditure aggregates, are mediocre.

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[37] For the current quarter, the quarter ahead, the current quarter and quarter ahead combined, and the current quarter with models using contemporaneous values of financial aggregates.

It should also be noted that none of the models is notably successful in predicting turning points.

To conclude this survey of the forecasting performance of the various indicator models, Table 13 presents a summary evaluation for each of the macroeconomic aggregates.

The existence of several different forecasts for nominal and real GDP growth and for the growth in the GDP deflator naturally raises the question of whether the forecast of the preferred model dominates (or encompasses) those of alternative models. In order to resolve this question, two equations relating the historical series of the goal variable (X) to the preferred-model forecast and to one of the alternative forecasts (XPA) were estimated. Equation (5) imposes no constraints on the constant term and on the sum of the slope coefficients in the equation:

$$X_t = \alpha_0 + \alpha_1 * XP_t + \alpha_2 * XPA_t + \mu_t . \tag{5}$$

An estimate of α_2 that is not statistically different from zero indicates that the forecast of the preferred model dominates that of the alternative.[38] The second equation is more restrictive in that it imposes the constraint that the sum of the two coefficients must be equal to unity. Following Holden and Peel (1989), equation (6) was written in terms of forecasting errors[39]:

$$(X_t - XP_t) = \beta_0 + \beta_2 * (XPA_t - XP_t) + \mu_t . \tag{6}$$

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[38] It also indicates that one of the necessary conditions for the preferred model dominating the alternative model is satisfied (Chong and Hendry, 1986).

[39] When the individual forecasts are biased (i.e., X_t-XP_t=$a+v_t$), estimating equation (6) produces efficient estimates of the weights to be applied to individual forecasts when they are combined.

Table 13
General Evaluation of the Forecasting Performance of Indicator Models for Various Goal Variables

Goal variable	Evaluation
GDP	
Current dollars	very good
Constant dollars	very good
Deflator	very good
Fixed-weight GDP deflator	very good
Consumer price index	very good
Private final demand	
Current dollars	good
Constant dollars	good
Deflator	very good
Household expenditures	
Current dollars	mediocre
Constant dollars	mediocre
Deflator	very good
Housing expenditures	
Current dollars	mediocre
Constant dollars	mediocre
Deflator	mediocre
Business fixed investment	
Current dollars	good
Constant dollars	good
Deflator	good

Table 14
Estimated Weights of Forecast Combinations
Models without contemporaneous financial aggregate values (1980Q2-1989Q2)

Equation (5): $X_t = \alpha_0 + \alpha_1 * XP_t + \alpha_2 * XPA_t + \mu_t$

Equation (6): $(X_t\text{-}XP_t) = \beta_0 + \beta_2 * (XPA_t\text{-}XP_t) + \mu_t$

Alternative model	Preferred model	Current quarter		One quarter ahead	
		α_2	β_2	α_2	β_2
GDP, Constant dollars	MBQ				
MMQ		*	*	*	*
C1Q		*	*	*	*
C2Q		*	*	*	*
GDP deflator	C1P				
MBP		0.68 (1.91)	0.61 (3.07)	0.67 (3.02)	0.66 (3.06)
MMP		0.28 (2.11)	0.24 (2.01)	0.21 (1.51)	0.24 (1.72)
Nominal GDP	MI1Y				
MBY		*	*	*	*
MMY		*	*	*	*
C1Y		*	*	*	*
C2Y		*	*	*	*
M1Y		*	*	*	*
M2Y		0.25 (1.69)	0.25 (1.73)	0.25 (1.66)	0.25 (1.75)
M3Y		*	*	*	*
M4Y		0.29 (1.43)	0.28 (1.48)	0.32 (1.51)	0.30 (1.38)
MC3Y		*	*	*	*

* statistically not significant (20 per cent or less) (cont'd)

Note:

X = historical series; XP = preferred-model forecast; and XPA = alternative-model forecast.
t - statistics in parentheses

Table 14 (cont'd)
Estimated Weights of Forecast Combinations
Models without contemporaneous financial aggregate values (1980Q2-1989Q2)

Equation (5): $X_t = \alpha_0 + \alpha_1 * XP_t + \alpha_2 * XPA_t + \mu_t$

Equation (6): $(X_t\text{-}XP_t) = \beta_0 + \beta_2 * (XPA_t\text{-}XP_t) + \mu_t$

Alternative model	**Preferred model**	**Current quarter**		**One quarter ahead**	
		α_2	β_2	α_2	β_2
Nominal GDP					
MC4Y		0.36	0.34	0.35	0.37
		(2.00)	(1.96)	(1.98)	(2.14)
MC5Y		*	*	*	*
MC6Y		*	*	*	*
MI2Y		0.43	0.29	0.51	0.43
		(1.58)	(1.78)	(1.81)	(1.54)
MI3Y		0.60	0.55	0.58	0.61
		(2.12)	(2.13)	(1.86)	(2.09)
MI4Y		0.47	0.38	0.44	0.45
		(2.59)	(2.64)	(2.43)	(2.41)
MI5Y		*	*	*	*
MI6Y		*	*	*	*
MI7Y		*	*	*	*
MI8Y		0.20	0.19	0.20	0.21
		(1.41)	(1.40)	(1.41)	(1.58)
COM1Y		*	*	*	*
COM2Y		*	*	*	*
MI1Y	combined forecast optimal deflator and real GDP forecasts**	*	*	*	*

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* statistically not significant (20 per cent or less)

** deflator forecast, $P_{opt} = 0.39*C1P + 0.61*MBP$, optimal real GDP forecast, Q = MBQ

Note:

X = historical series; XP = preferred-model forecast; and XPA = alternative-model forecast.
t - statistics in parentheses

The results reported in Table 14 show that the preferred model's forecast of GDP growth in constant dollars is optimal and dominates the forecasts of all alternative models.[40] For growth in the GDP deflator, however, the results indicate that the forecast of the preferred model does not dominate those of all the other models. However, combining the forecast of the preferred model based on bank household credit with that of the M2-based alternative model produces an optimal forecast. The performance of this combination is slightly better than that of the preferred model (Table 15).

The preferred model's forecast of nominal GDP growth also does not dominate all the forecasts of alternative models (Table 14). Moreover, the nominal GDP growth forecast obtained from forecasts of GDP growth in constant dollars and the optimal forecast of GDP deflator growth[41] is dominated by the preferred model's forecast.

The alternative models whose forecasts contribute additional information to the preferred-model forecast are almost identical to the preferred model. Like it, they add together the forecasts of real GDP growth based on real M1 growth and forecasts of GDP deflator growth based on bank consumer credit; the difference is that the underlying models generally include additional financial variables. The practical gains associated with using weighted forecasts are quite small and, in our opinion, do not offset the inconvenience of the added complexity that results from such combinations, which are themselves combinations of various volume and price forecasts and the breakdown of the accounting identity between nominal and real growth and prices.

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[40] The analysis of forecasts was done only for models without contemporaneous values of financial aggregates, since these models generally perform better than models with contemporaneous values.

[41] This forecast is constructed as follows:
$P_{opt} = 0.39*C1P + 0.61*MBP$
P_{opt} = the optimal price forecast and indices C1P and MBP refer to the indicator models.

Table 15
Comparison of Properties of Preferred-Model Forecasts and Optimal Forecast (1980Q1-1989Q2)

	Preferred model			Optimal forecast		
	ρ	ME	RMSE	ρ	ME	RMSE
Current-quarter forecast						
GDP deflator						
C1P	0.83	-0.12	0.44			
MBP	0.86	-0.14	0.42			
P_{opt}				0.87	-0.13	0.40
Nominal GDP						
MI1Y (MBQ+C1P)	0.74	-0.14	0.67			
M1Y (MBQ+MBP)	0.67	-0.17	0.74			
alternative, $(MBQ+P_{opt})$				0.71	-0.16	0.69
One-quarter-ahead forecast						
GDP deflator						
C1P	0.78	-0.16	0.39			
MBP	0.83	-0.19	0.37			
P_{opt}				0.85	-0.18	0.45
Nominal GDP						
MI1Y (MBQ+C1P)	0.68	-0.18	0.72			
M1Y (MBQ+MBP)	0.63	-0.39	0.63			
alternative, $(MBQ+P_{opt})$				0.67	-0.20	0.74

P_{opt} = 0.39*C1P + 0.61*MBP

ρ = correlation coefficient, ME = mean error, RMSE = root-mean-squared error

Table 16
Correlation of Forecast Errors of GDP Deflator and Constant Dollar GDP Growth (1980Q1-1989Q2)

	C1P	MBP	P_{opt}*
MBQ	-0.50	-0.31	-0.42
C1P	-	0.71	0.89
MBP	-	-	0.95

* P_{opt} = 0.39*C1P + 0.61*MBP

Table 17
Current-Quarter and One-Quarter-Ahead Forecasts and Actual Data (1980Q2-1989Q2)

Current quarter

Goal variable	Model	α_0	α_1	rho	$\bar{R}^2$	D.W.
GDP						
Constant dollars	MBQ	-0.08 (0.42)	1.07 (5.55)	-	0.45	1.65
Deflator	C1P	-0.21 (1.13)	1.07 (8.77)	-	0.68	1.75
	MBP	-0.15 (0.95)	1.01 (9.93)	-	0.73	1.80
	P_{opt}[1]	-0.26 (1.60)	1.09 (10.51)	-	0.75	1.92
Current dollars	MI1Y (MBQ+C1P)	-0.02 (0.03)	0.94 (4.33)	0.37 (2.04)	0.57	1.92
	alt. (MBQ+P_{opt})	0.16 (0.31)	0.86 (3.98)	0.40 (2.35)	0.55	1.86
Fixed-weight						
GDP deflator	MFW	0.03 (0.18)	0.88 (8.66)	-	0.67	1.88
Consumer						
price index	MCPI	-0.18 (1.08)	1.11 (11.09)	-	0.77	1.92

1. $P_{opt} = 0.39*C1P + 0.61*MBP$ (cont'd)
2. rho = estimated autocorrelation coefficient

Note:
$X_t = \alpha_0 + \alpha_1 * XP_t + \mu_t$
X_t = actual, XP_t = forecast
t - statistics in parentheses

Table 17 (cont'd)
Current-Quarter and One-Quarter-Ahead Forecasts and Actual Data (1980Q2-1989Q2)

One quarter ahead

Goal variable	Model	α_0	α_1	rho	$\bar{R}^2$	D.W.
GDP						
Constant dollars	MBQ	-0.09	1.07	-	0.44	1.55
		(0.43)	(5.41)			
Deflator	C1P	-0.29	1.09	-	0.59	1.14
		(1.25)	(7.30)			
	MBP	-0.16	0.98	-	0.68	1.33
		(0.90)	(8.88)			
	P_{opt}	-0.34	1.11	-	0.71	1.37
		(1.80)	(9.39)			
Current dollars	MI1Y	0.27	0.80	0.46	0.53	1.87
	(MBQ+C1P)	(0.49)	(3.44)	(2.66)		
	alt.	0.30	0.78	0.47	0.53	1.80
	(MBQ+P_{opt})	(0.55)	(3.50)	(2.79)		
Fixed-weight GDP deflator	MFW	0.01	0.86	-	0.65	1.40
		(0.05)	(8.23)			
Consumer price index	MCPI	-0.23	1.13	-	0.72	1.33
		(1.20)	(9.73)			

1. $P_{opt} = 0.39 * C1P + 0.61 * MBP$
2. rho = estimated autocorrelation coefficient

Note:
$X_t = \alpha_0 + \alpha_1 * XP_t + \mu_t$
X_t = actual, XP_t = forecast
t - statistics in parentheses

The fact that the forecasts of the preferred nominal GDP model also dominate those combining optimal, efficient and non-biased forecasts (Table 17) of GDP growth in constant dollars and GDP deflator growth, also leads to marginally better performance scores (Table 15). The preferred model fares better because the forecasting errors associated with the GDP growth rate in constant dollars and the GDP deflator growth rate tend to partially offset each other over the evaluation period and because the negative correlation coefficient between the forecasting errors of the models used in the composite preferred model is greater, in absolute terms, than the correlation coefficient of the errors of the optimal volume and price forecasts (Table 16). Users of such indicator models, therefore, face a trade-off between coherent forecasts of the nominal macroeconomic aggregate and its price and volume components on the one hand, and maximum forecasting efficiency, on the other. Since this utilizes the negative correlation between the forecasting errors of the price and volume components, accounting consistency is destroyed.

The main conclusions that may be drawn from this detailed survey of the forecasting performance of the various indicator models are as follows:

- For all the major macroeconomic aggregates - nominal and real GDP, the GDP deflator and the CPI - and for virtually all the components of private demand, it is not necessary to use indicator models that include contemporaneous values from financial aggregates. Models that use only lagged values function equally well.

- The models provide adequate forecasts of the growth of the major macroeconomic aggregates. However, their forecasts of the private final demand components are often less satisfactory.

- Models employing a single financial aggregate and no other financial variables generally have the best performance.

- The best models of the major macroeconomic aggregates use only three financial aggregates: M1 (deflated by the CPI) in the case of real GDP, and bank consumer credit or M2 in the case of the GDP deflator. M2 also serves to predict developments in the fixed-weight GDP deflator and the CPI. The best forecast of nominal GDP growth is equal to the sum of the forecast of real GDP growth based on M1 in real terms and the forecast of the growth in the GDP deflator based on bank consumer credit.

- Using seasonally adjusted data does not affect our conclusions concerning the indicator models of constant dollar GDP growth and of the GDP deflator. The estimation results reported in Table A5.1 show that the coefficients of M1 (in real terms) and of bank consumer credit even increase when seasonally unadjusted variables are used and seasonal dummies are added to the indicator-model equation.

- The relationship between constant dollar GDP growth and the growth of M1 in real terms is linear. In contrast to some U.S. studies that indicate that a drop in M1 has a stronger effect than a rise in M1,[42] the addition of an extra variable just to reflect declines in M1 does not have any explanatory power (Table A5.2). Adding the squared growth rate of M1 also does not improve the fit of the equation.

- Lastly, the indicator model of constant dollar GDP growth encompasses Statistics Canada's leading indicator,[43] if the indicator model is used as soon as financial data become available. Because complete quarterly data for Statistics Canada's leading indicator are not released until two months after the end of the quarter, the value of this indicator in quarter t is not useful for forecasting GDP growth in quarter t+1. Moreover, the coefficients of the leading indicator lagged two or three quarters are not statistically significant in an expanded version of the indicator model (Table A5.3 in the appendix).

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[42] See, for example, De Long and Summers (1988).

[43] The purpose of the leading indicator is to anticipate new cyclical economic trends. The ten components of this indicator are: furniture and appliance sales, retail sales of durables, housing expenditures, the U.S. leading indicator, the ratio of deliveries to inventories of finished goods, new orders for durables, the average work week, employment in services to individuals and businesses, the TSE price index (TSE300), and the monetary aggregate M1. For more information on the leading indicator and its performance, see Cross and Roy-Mayrand (1989).

5. Indicator-Model Forecasts and Revised National Accounts Data

Given that the first releases of the national accounts are subject to numerous revisions, an interesting question is whether indicator-model forecasts might provide information that could be used to increase the accuracy of these estimates. Generally speaking, national accounts data on economic activity in quarter t (first release) are published towards the end of the second month of quarter t+1. These data are subsequently revised when data for following quarters in the same year are released, as well as in June of the following four years when first-quarter data are released. The data are also subject to periodic revision at the time of five- and ten-year updates of the national accounts.[44]

The following section examines, first of all, whether indicator-model forecasts can anticipate the initial revisions of these data (second release) that are made available in quarter t+2. To this end, equation (7), which relates the second release (SR) of quarterly GDP growth and its price and volume components during quarter t to indicator-model forecasts for quarter t (indicator model) and the first release (FR), was estimated for the 1980Q1-1989Q3 period. The indicator-model forecasts used for this exercise were based solely on data available at the time of the forecast in question. For example, the forecast of the growth in the major macroeconomic aggregates in the first quarter of 1980 was produced by models using the national accounts data set released in February 1980, covering up to the fourth quarter of 1979.[45]

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[44] See Clift and Wells (1990) for more information on the national accounts revision process and on the quantitative importance of the revisions.

[45] The forecasting performance of these models, using data available at the time the forecast would have been made, is essentially the same as that of the models using data available as of February 1990, which were discussed in the previous section. Using February 1990 data as a benchmark, the mean forecast error of the model of real GDP growth is -0.04 for models using available historical data and -0.03 for models using February 1990 data exclusively. The mean forecast error of growth in the GDP deflator is -0.18 and -0.12, respectively.

The indicator models used for this analysis are simple money models using lagged financial aggregate values exclusively. The model with the M1 aggregate in real terms (model MBQ) provides a forecast of GDP growth in constant dollars, and the model using M2 (model MBP) provides a forecast of the growth of the GDP deflator.[46] The forecast of nominal GDP growth is simply the sum of the forecasts of growth in the price and volume components.[47]

$$SR_t = \alpha_0 + \alpha_1 * \text{ind. mod.}_t + \alpha_2 * FR_t \,. \qquad (7)$$

We also considered the possibility that the indicator-model forecasts contained information found in subsequent revisions. To test this hypothesis, we estimated equation (8), which relates most recent data (FD) to the first release of quarter t data and to the indicator-model forecasts for this quarter. The final data are those available as of February 1990.

$$FD_t = \alpha_0 + \alpha_1 * \text{ind. mod.}_t + \alpha_2 * FR_t \,. \qquad (8)$$

Since, in the preliminary estimations, the estimated constant for each of these equations was not statistically different from zero, and the sum of the estimated slope coefficients, $\alpha_1 + \alpha_2$, was not statistically different from unity (Table 18.1), these two constraints were imposed in the estimation results reported in Table 18.2. The main results are as follows:

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[46] The preferred GDP deflator model, which is based on bank household credit (model C1P), is not used here because the credit data that the forecast would have used at the time no longer exist in data banks.

[47] The major macroeconomic aggregates were originally constructed on the basis of gross national product (GNP). With the publication of the national accounts in June 1986, however, gross domestic product (GDP) became the standard of reference for the national accounts. For this reason, our study uses forecasts and revisions of quarterly nominal GNP growth and its price and volume components up to the first quarter of 1986, and quarterly GDP growth and its price and volume components thereafter.

Table 18.1
Indicator-Model Forecasts and First, Second and Most Recent Releases of National Accounts Data (1980Q1-1989Q3)

First (FR) and Second Releases (SR)

Equation (7): $SR_t = \alpha_0 + \alpha_1 * \text{ind. mod.}_t + \alpha_2 * FR_t$

	α_0	α_1	α_2	$\bar{R}^2$	D.W.
GDP					
Current dollars	-0.272	0.228	0.902	0.91	1.88
	(1.71)	(3.87)	(18.04)		
Constant dollars	0.016	0.028	1.000	0.95	2.41
	(0.41)	(0.65)	(31.19)		
Deflator	-0.031	0.228	0.769	0.83	1.51
	(0.24)	(2.35)	(9.32)		

First (FR) and Most Recent Data (FD)

Equation (8): $FD_t = \alpha_0 + \alpha_1 * \text{ind. mod.}_t + \alpha_2 * FR_t$

	α_0	α_1	α_2	$\bar{R}^2$	D.W.
GDP					
Current dollars	-0.109	0.318	0.765	0.73	1.77
	(0.40)	(3.19)	(8.98)		
Constant dollars	0.276	0.017	0.837	0.79	2.15
	(2.63)	(0.16)	(9.79)		
Deflator	0.037	0.474	0.422	0.70	1.28
	(0.24)	(4.07)	(4.26)		

Table 18.2
Indicator-Model Forecasts and First, Second and Most Recent Releases of National Accounts Data

First (FR) and Second Releases (SR)

Equation (7): $SR_t = \alpha * \text{ind. mod.}_t + (1-\alpha) * FR_t$

	Nominal GDP			Real GDP			GDP deflator		
	α	$\bar{R}^2$	D.W.	α	$\bar{R}^2$	D.W.	α	$\bar{R}^2$	D.W.
1980Q1-1989Q3	0.152	0.90	1.73	0.016	0.97	2.14	0.220	0.84	1.48
	(3.84)			(0.53)			(2.91)		
1980Q1-1983Q4	0.112	0.91	1.63	-0.026	0.98	2.92	0.254	0.72	1.36
	(1.63)			(0.60)			(1.60)		
1984Q1-1989Q3	0.211	0.89	2.54	0.125	0.93	2.00	0.188	0.85	1.93
	(5.19)			(3.05)			(3.49)		
1980Q1-1985Q4	0.096	0.91	1.94	-0.018	0.87	2.36	0.168	0.83	1.37
	(1.71)			(0.48)			(1.59)		
1986Q1-1989Q3	0.260	0.92	2.11	0.155	0.97	1.38	0.392	0.83	2.55
	(7.12)			(4.57)			(6.43)		

First (FR) and Most Recent Data (FD)

Equation (8): $FD_t = \alpha * \text{ind. mod.}_t + (1-\alpha) * FR_t$

	Nominal GDP			Real GDP			GDP deflator		
	α	$\bar{R}^2$	D.W.	α	$\bar{R}^2$	D.W.	α	$\bar{R}^2$	D.W.
1980Q1-1989Q3	0.289	0.73	1.61	0.180	0.76	1.87	0.516	0.68	1.23
	(4.41)			(2.10)			(5.42)		
1980Q1-1986Q4	0.285	0.73	1.48	0.164	0.75	1.86	0.572	0.69	1.17
	(3.56)			(1.60)			(5.01)		
1980Q1-1983Q4	0.316	0.73	1.48	0.156	0.82	1.64	0.583	0.28	1.02
	(2.83)			(1.35)			(3.15)		
1984Q1-1986Q4	0.214	0.69	2.26	0.191	0.34	1.91	0.559	0.20	1.69
	(1.96)			(0.84)			(4.86)		
1980Q1-1983Q4*	0.371	0.83	1.28	0.203	0.89	1.86	0.588	0.67	1.37
	(4.05)			(2.07)			(2.88)		

* **Estimated with national accounts data up to 1983Q4 released in February 1984.**

Table 19
Improvement in National Accounts Data due to Combination with Indicator-Model Forecasts
(Revision in quarterly growth rate of goal variable)

Second release versus combination of first release and indicator-model forecast
1986Q1-1989Q3
(using equation estimated for 1980Q1-1985Q4)

	Mean revision[1]		Root-mean-square revision	
	Second - First	Second - Combination	Second - First	Second - Combination
Nominal GDP	0.15	0.12	0.32	0.24
Real GDP	0.08	0.06	0.13	0.14
GDP deflator	0.06	0.05	0.26	0.18

Most recent release versus combination of first release and indicator-model forecast
1984Q1-1986Q4
(using equation estimated for 1980Q1-1983Q4)

	Mean revision[2]		Root-mean-square revision	
	Most recent - First	Most recent - Combination	Most recent - First	Most recent - Combination
Nominal GDP	0.10	-0.01	0.46	0.50
Real GDP	0.17	0.15	0.59	0.56
GDP deflator	-0.07	-0.17	0.55	0.31

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1. Revision: second release - first release.
2. Revision: most recent release - first release.

- The indicator-model forecasts, particularly those for nominal GDP growth and GDP deflator growth, contain information that is not provided by the first release of the national accounts.

- The hypothesis that the estimation results are stable cannot be rejected when the original estimation period is split into two parts. However, the estimated weights of the indicator-model forecasts are slightly higher for the estimation period covering the second half of the 1980s.

- The estimated weights of the indicator models are higher when the combinations of first-release data and forecasts serve to anticipate the final data, proxied by the most recent data.

- In practice, using such combinations (first-release data and indicator-model forecasts) would not, on average, help reduce the size of revisions. However, some of the major revisions may be anticipated. The lower root mean square of the revisions indicates that, in certain cases, these combinations reduce the extent of individual revisions.

- Combining the first-release data and the indicator-model forecasts using weights derived from the estimation of equation (7) over the 1980Q1-1985Q4 period would have had virtually no effect on the mean revision during 1986Q1-1989Q3 (Table 19). However, it would have served to anticipate some of the more important revisions.

- Similar conclusions may be reached when revisions between first-release and final data are compared. By using weights resulting from the estimation of equation (8) over the 1980Q1-1983Q4 period, as well as final data from the February 1984 release, the average revision of the nominal GDP growth rate would have been reduced to zero over the 1984Q1-1986Q4 period.[48] However, the mean revision of the GDP deflator would have risen slightly.

- According to equation (8) estimated over the 1980Q1-1986Q4 period, a slight downward revision in the average quarterly rate of nominal GDP growth could be expected in 1987 and 1988, and a slight upward revision in 1989. The average GDP growth rate in constant dollars should be revised downward over the three years, while the nominal GDP deflator should be reduced very marginally in 1988 and revised upward in 1989 (Table 20).

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[48] The comparison of predicted revisions with final data stops at the end of 1986 because the national accounts data for the years 1987-1989 are still far from final.

Table 20
Anticipated Revision of National Accounts Data: 1987Q1-1989Q3
Combination of first release and indicator-model forecasts minus first release
(Revision of quarterly growth rate of goal variable)

GDP		**Nominal**	**Real**	**Deflator**
1987	**Q1**	-0.37	-0.14	-0.21
	Q2	0.13	-0.01	0.16
	Q3	-0.23	-0.42	0.20
	Q4	0.12	0.11	0.03
1988	**Q1**	-0.32	-0.15	-0.16
	Q2	-0.41	-0.46	0.05
	Q3	-0.46	-0.14	-0.32
	Q4	0.06	-0.06	0.14
1989	**Q1**	0.01	0.13	-0.11
	Q2	0.30	-0.19	0.50
	Q3	0.14	-0.03	0.18

6. The Information Content of Indicator-Model Forecasts Versus Private-Sector Forecasts

The accuracy of short-term Canadian macroeconomic forecasts carried out by private-sector firms has already been thoroughly examined in several papers by Daub (1973, 1981 and 1987). None of these studies, however, explores the possibility that forecasts might yield better results in combination rather than individually. This section investigates whether the forecasts generated by indicator models provide information that is not contained in publicly available forecasts, so that combining these two types of forecasts would be worthwhile. The indicator models used here are the same ones used previously for predicting national accounts revisions (Section 5), i.e., model MBQ using M1 in real terms to predict constant dollar GDP growth, model MBP using M2 to predict the growth of the GDP deflator, and model M1Y combining forecasts of constant dollar GDP and GDP deflator growth to predict nominal GDP growth.[49] The forecasts of these models are those that would have been made using data available at the time.

To determine the weights that should be accorded to the various forecasts, equations (9), (10) and (11) were estimated. These equations relate the actual growth rate of the goal variable, X, to the growth rate provided by the private-sector forecast, Xpriv., and to the growth rate predicted by the indicator model, XP. For each of the three goal variables (nominal GDP and its price and volume components[50]), three different cases were examined. The first equation relates private-sector forecasts, $Xpriv._t$, and the indicator-model forecast, XP_t, made for quarter t in quarter t (current-quarter forecasts) to historical data from quarter t, X_t. The second equation relates private-sector forecasts, $Xpriv._{t+1,t}$, and the indicator-model forecast, $XP_{t+1,t}$, made in quarter t for quarter t+1 (one-quarter-ahead forecasts) to historical data from quarter t+1. Lastly, the third equation combines the forecasts made in quarter t of the growth of the goal variables during quarters t and t+1 made by the private sector, $Xpriv._{(t+t+1)}$, and by the indicator models, $XP_{(t+t+1)}$.

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49. The results of combining private-sector forecasts with the forecasts of other indicator models based on monetary aggregates (models MMQ, MMP, MBY, MMY and M2Y through M4Y) are presented in Muller (1989). Only the forecasts generated by the best indicator models in terms of forecasting performance are used here.

50. Prior to the second quarter of 1986, the goal variables are nominal GNP and its price and volume components.

$$X_t = \alpha_0 + \alpha_1 * Xpriv._t + \alpha_2 * XP_t + \mu_t . \qquad (9)$$

$$X_{t+1} = \alpha_0 + \alpha_1 * Xpriv._{t+1,t} + \alpha_2 * XP_{t+1,t} + \mu_{t+1} . \qquad (10)$$

$$X_{(t+t+1)} = \alpha_0 + \alpha_1 * Xpriv._{(t+t+1),t} + \alpha_2 * XP_{(t+t+1),t} + \mu_{(t+t+1)} . \qquad (11)$$

If both types of forecast contain useful and independent information, the estimated values of α_1 and α_2 will be statistically different from zero. If both forecasts contain useful information, but the information provided by one encompasses that of the other, the coefficient of the latter will not be statistically different from zero. If the two types of forecast supply the same information, it will not be possible to identify the two coefficients α_1 and α_2 separately.

Because the national accounts are revised frequently, it is not clear which data should be used as a benchmark for evaluation purposes. The results reported in Tables 21, 22 and 23 are based on two sets of benchmark data. In the first case, the benchmark data are national accounts data as first released by Statistics Canada and, in the second, the set of national accounts data released in February 1989. The difference between these two data sets reflects the normal quarterly revisions to the national accounts throughout the year, the normal yearly revisions released in June of the following four years, the decennial revision of the national accounts in June 1986, and a special revision in June 1987 that affected the four years prior to 1987. The publicly available forecasts used in this exercise are from the Conference Board of Canada and from DRI of Canada, two of the major private forecasting organizations.[51]

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[51] The quarterly forecasts for the current quarter and one quarter ahead delivered by these two organizations over the 1980Q1-1988Q4 period are presented in Muller (1989).

The results shown in Tables 21 through 23 imply that the forecasts of the indicator model do not contain information about nominal GDP growth that is not already embodied in the private-sector forecasts. On the other hand, the indicator-model forecasts of constant dollar GDP made in quarter t for quarter t+1 (one-quarter-ahead forecast) do provide some information not contained in the Conference Board forecast.[52] Lastly, the indicator-model forecasts of the growth of the GDP deflator supply additional information for all forecasting horizons relative to the Conference Board forecasts and relative to the current-quarter forecast by DRI when February 1989 data are used as the benchmark.

7. Conclusions

The main conclusion that may be drawn from this in-depth study of the information contained in financial aggregates is that the answer to the question posed at the beginning of this paper is "yes." Despite the many financial innovations that have affected the relationship between financial aggregates and total spending, these aggregates remain extremely useful sources of information on developments in the major macroeconomic aggregates. There is no reason yet to discard them.

First, in terms of simple contemporaneous links between the quarterly growth in financial aggregates and the quarterly growth in the major macroeconomic aggregates, the broad monetary aggregates (M2, M2+, M3, and M3+) follow total spending most closely in the long run. This link is less strong, however, in the short run, and thus any estimate of growth in nominal

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[52] The one-quarter-ahead forecasts produced by the indicator model MMQ also add information relative to the DRI forecasts (see Muller, 1989).

Table 21
Combination of Private-Sector and Indicator-Model M1Y Forecasts
Nominal GDP growth
(1980Q3-1988Q4)

Equation (9): $X_t = \alpha_0 + \alpha_1 * \text{Xpriv}_{-t} + \alpha_2 * XP_t + \mu_t$

Equation (10): $X_{t+1} = \alpha_0 + \alpha_1 * \text{Xpriv}_{-t+1,t} + \alpha_2 * XP_{t+1,t} + \mu_{t+1}$

Equation (11):
$$X_{(t+t+1)} = \alpha_0 + \alpha_1 * \text{Xpriv}_{-(t+t+1),t} + \alpha_2 * XP_{(t+t+1),t} + \mu_{(t+t+1)}$$

Equation reference data	Conference Board			
	α_0	α_1	α_2	$\bar{R}^2$ D.W.
(9) First release	0.872 (2.14)	0.865 (4.58)	-0.250 (1.34)	0.40 1.66
Feb. 1989 revision	0.566 (1.62)	0.920 (5.69)	-0.098 (0.61)	0.55 1.39
(10) First release	1.147 (1.85)	0.320 (1.17)	0.054 (0.28)	-0.06 1.34
Feb. 1989 revision	1.220 (1.76)	0.246 (0.85)	0.177 (1.07)	0.22* 1.88
(11) First release	2.167 (1.63)	0.361 (1.19)	0.081 (0.64)	0.44* 1.48
Feb. 1989 revision	2.028 (1.76)	0.546 (2.30)	-0.033 (0.31)	0.63* 1.37

* Corrected for first-order correlation.

(cont'd)

Table 21 (cont'd)
Combination of Private-Sector and Indicator-Model M1Y Forecasts
Nominal GDP growth
(1980Q3-1988Q4)

Equation (9): $X_t = \alpha_0 + \alpha_1 * Xpriv_{\cdot t} + \alpha_2 * XP_t + \mu_t$

Equation (10): $X_{t+1} = \alpha_0 + \alpha_1 * Xpriv_{\cdot t+1,t} + \alpha_2 * XP_{t+1,t} + \mu_{t+1}$

Equation (11): $X_{(t+t+1)} = \alpha_0 + \alpha_1 * Xpriv_{\cdot (t+t+1),t}$
$+ \alpha_2 * XP_{(t+t+1),t} + \mu_{(t+t+1)}$

Equation reference data	DRI α_0	α_1	α_2	$\bar{R}^2$ D.W.
(9) First release	0.391	0.760	-0.052	0.22
	(0.70)	(3.19)	(0.28)	1.46
Feb. 1989 revision	0.889	0.426	0.099	0.31*
	(1.35)	(1.71)	(0.53)	2.05
(10) First release	1.123	0.281	0.121	0.00
	(1.78)	(1.02)	(0.66)	1.43
Feb. 1989 revision	1.456	0.194	0.094	0.25*
	(2.06)	(0.63)	(0.54)	1.99
(11) First release	2.350	0.360	0.039	0.45*
	(2.10)	(1.74)	(0.24)	1.42
Feb. 1989 revision	2.774	0.258	0.061	0.58*
	(2.40)	(1.35)	(0.42)	1.31

* Corrected for first-order correlation.

Table 22
Combination of Private-Sector and Indicator-Model MBQ Forecasts
GDP growth in constant dollars
(1980Q3–1988Q4)

Equation (9): $X_t = \alpha_0 + \alpha_1 * Xpriv._t + \alpha_2 * XP_t + \mu_t$

Equation (10): $X_{t+1} = \alpha_0 + \alpha_1 * Xpriv._{t+1,t} + \alpha_2 * XP_{t+1,t} + \mu_{t+1}$

Equation (11):
$$X_{(t+t+1)} = \alpha_0 + \alpha_1 * Xpriv._{(t+t+1),t} + \alpha_2 * XP_{(t+t+1),t} + \mu_{(t+t+1)}$$

Equation **reference data**		Conference Board			
		α_0	α_1	α_2	$\bar{R}^2$ D.W.
(9)	**First release**	0.016 (0.10)	1.115 (5.53)	0.142 (0.87)	0.64 1.84
	Feb. 1989 revision	0.252 (1.57)	1.064 (5.25)	0.058 (0.35)	0.59 1.88
(10)	**First release**	-0.011 (0.03)	0.100 (0.22)	**0.705** (3.12)	0.23 1.37
	Feb. 1989 revision	0.259 (0.82)	0.065 (0.14)	**0.591** (2.66)	0.17 1.60
(11)	**First release**	0.439 (0.54)	0.819 (2.20)	0.089 (0.59)	0.63* 1.33
	Feb. 1989 revision	0.816 (1.14)	0.724 (2.13)	0.015 (0.10)	0.57 1.40

* Corrected for first-order correlation.

(cont'd)

Table 22 (cont'd)
Combination of Private-Sector and Indicator-Model MBQ Forecasts
GDP growth in constant dollars
(1980Q3-1988Q4)

Equation (9): $X_t = \alpha_0 + \alpha_1 * Xpriv_{-t} + \alpha_2 * XP_t + \mu_t$

Equation (10): $X_{t+1} = \alpha_0 + \alpha_1 * Xpriv_{-t+1,t} + \alpha_2 * XP_{t+1,t} + \mu_{t+1}$

Equation (11):
$$X_{(t+t+1)} = \alpha_0 + \alpha_1 * Xpriv_{-(t+t+1),t} + \alpha_2 * XP_{(t+t+1),t} + \mu_{(t+t+1)}$$

		DRI		
Equation reference data	α_0	α_1	α_2	$\bar{R}^2$ D.W.
(9) First release	-0.116 (0.64)	0.953 (4.22)	0.233 (1.25)	0.54 1.49
Feb. 1989 revision	0.077 (0.42)	0.995 (4.36)	0.116 (0.61)	0.502 2.14
(10) First release	0.198 (0.60)	0.548 (1.67)	0.228 (0.95)	0.38* 1.76
Feb. 1989 revision	0.147 (0.66)	0.648 (2.29)	0.343 (1.56)	0.298 1.49
(11) First release	0.697 (0.96)	0.436 (1.57)	0.171 (0.78)	0.66 1.32
Feb. 1989 revision	0.826 (1.36)	0.540 (2.03)	0.084 (0.40)	0.61* 1.53

* Corrected for first-order correlation.

Table 23
Combination of Private-Sector and Indicator-Model MBP Forecasts
GDP deflator growth
(1980Q3–1988Q4)

Equation (9): $X_t = \alpha_0 + \alpha_1 * \text{Xpriv}_{-t} + \alpha_2 * XP_t + \mu_t$

Equation (10): $X_{t+1} = \alpha_0 + \alpha_1 * \text{Xpriv}_{-t+1,t} + \alpha_2 * XP_{t+1,t} + \mu_{t+1}$

Equation (11): $$X_{(t+t+1)} = \alpha_0 + \alpha_1 * \text{Xpriv}_{-(t+t+1),t} + \alpha_2 * XP_{(t+t+1),t} + \mu_{(t+t+1)}$$

Equation reference data	Conference Board			
	α_0	α_1	α_2	$\bar{R}^2$ D.W.
(9) First release	-0.432 (1.35)	0.563 (4.96)	0.477 (4.48)	0.78 1.76
Feb. 1989 revision	-0.144 (0.89)	0.507 (5.40)	0.490 (4.76)	0.75 1.72
(10) First release	-0.078 (0.29)	0.799 (3.80)	0.178 (0.94)	0.52 1.62
Feb. 1989 revision	-0.304 (2.31)	0.798 (7.81)	0.302 (3.20)	0.85 1.67
(11) First release	-0.461 (1.47)	0.631 (5.71)	0.443 (4.37)	0.79 1.76
Feb. 1989 revision	0.582 (1.02)	0.348 (2.85)	0.272 (2.53)	0.87* 1.68

* Corrected for first-order correlation.

(cont'd)

Table 23 (cont'd)
Combination of Private-Sector and Indicator-Model MBP Forecasts
GDP deflator growth
(1980Q3-1988Q4)

Equation (9): $X_t = \alpha_0 + \alpha_1 * Xpriv_{\cdot t} + \alpha_2 * XP_t + \mu_t$

Equation (10): $X_{t+1} = \alpha_0 + \alpha_1 * Xpriv_{\cdot t+1,t} + \alpha_2 * XP_{t+1,t} + \mu_{t+1}$

Equation (11): $$X_{(t+t+1)} = \alpha_0 + \alpha_1 * Xpriv_{\cdot(t+t+1),t} + \alpha_2 * XP_{(t+t+1),t} + \mu_{(t+t+1)}$$

		DRI			
Equation reference data		α_0	α_1	α_2	$\bar{R}^2$ D.W.
(9)	First release	0.019	0.681	0.174	0.52
		(0.07)	(3.66)	(0.80)	1.90
	Feb. 1989 revision	0.058	0.491	0.349	0.67
		(0.03)	(3.85)	(2.33)	1.64
(10)	First release	-0.067	0.869	0.086	0.53
		(0.26)	(3.98)	(0.38)	1.67
	Feb. 1989 revision	0.357	0.554	0.062	0.78*
		(1.13)	(3.72)	(0.41)	1.84
(11)	First release	-0.444	0.776	0.232	0.78
		(1.36)	(5.99)	(1.75)	1.63
	Feb. 1989 revision	1.791	0.108	-0.027	0.84*
		(1.64)	(0.95)	(0.24)	1.38

* Corrected for first-order correlation.

GDP made on the basis of the broad monetary aggregates must be treated with some caution.

Second, it has been shown that it is possible to construct indicator models using either lagged variables exclusively or contemporaneous and lagged values of financial aggregates and other financial variables. Although it might be assumed *a priori* that models of this kind are particularly vulnerable to the Lucas critique, we have demonstrated that these models are remarkably stable over the past fifteen years, despite changes in monetary policy regimes and numerous innovations. Among the many models studied, those of the major macroeconomic aggregates were the most successful in terms of forecasting performance. The models of the demand components performed less well and do not merit consideration as information sources.

When it comes to the major macroeconomic aggregates, it is not necessary to retain models that employ lagged financial aggregate values exclusively to predict current-quarter and quarter-ahead developments in the macroeconomic aggregates as well as models that add contemporaneous financial aggregate values to predict the current quarter. The performance of the former group of models is typically better than that of the latter. Models using a single financial aggregate and no other financial variable as an explanatory variable yield better forecasts than those using a number of financial variables. Thus, the simplest models will be the preferred models.

These models use only a small number of financial aggregates. The aggregate M1, deflated by the consumer price index, serves to explain real GDP growth, consumer bank credit serves to explain GDP deflator developments, and predicted nominal GDP growth is simply the sum of the forecasts of the growth of price and volume components. The aggregate M2 may be used to generate an alternative forecast of GDP deflator growth as well as forecasts of growth in the fixed-weight GDP deflator and the consumer price index.

Lastly, it has also been shown that the forecasts produced by these models can anticipate some of the revisions to national accounts data, although the increase in accuracy is generally small. Furthermore, research indicates that some of the publicly available macroeconomic forecasts do not embody all the available information and that it is possible to improve the quality of these forecasts by combining them with indicator-model forecasts.

The results of this study have modified initial scepticism, and the conclusion is that, despite the multitude of financial innovations and shifts in monetary policy, financial aggregates will continue to play a role in the development of monetary policy, although this role will likely be more restricted than it was during the 1970s.

Appendix 1

Variable Definitions and Data Sources

Macroeconomic aggregates (Quarterly data, seasonally adjusted)		CANSIM
Y	GDP, current dollars	D20011
Q	GDP, constant dollars	D20031
P	GDP deflator	D20337
C$	Household expenditures, current dollars	D20012
C	Household expenditures, constant dollars	D20032
PC	Household expenditures deflator	D20338
I$	Business fixed investment, current dollars	D20018 + D20019
I	Business fixed investment, constant dollars	D20038 + D20039
PI	Business fixed investment deflator	I$/I
H$	Housing, current dollars	D20017
H	Housing, constant dollars	D20037
PH	Housing deflator	H$/H
DD$	Private demand, current dollars	C$ + H$ + I$
FWP	Fixed-weight GDP deflator	D20358
CPI	Consumer price index, quarterly average of monthly observations	D484549
Inv. $	Farm and non-farm inventories, current dollars	D20021 + D20022
Inv.	Farm and non-farm inventories, constant dollars	D20042 + D20043
Pinv.	Inventory deflator	Inv. $/Inv.
Trade $	Trade balance, current dollars	D20023-D20026
Trade	Trade balance, constant dollars	D20044-D20048
Ptrade	Trade balance deflator	Trade $/Trade
Oil	World oil price, U.S. dollars per barrel	Bank of Canada
LIND	Statistics Canada leasing indicator, quarterly average of monthly data	D999947

Financial aggregates (Quarterly average of monthly observations)	
M1	B1627
M2	B1630
M2+	B1633
M3	B1628
M3+	M3 + (M2+ - M2)

(cont'd)

Variable Definitions and Data Sources (cont'd)

Financial aggregates
(Quarterly average of monthly observations)

		CANSIM
M1R	M1/CPI	
M2R	M2/CPI	
CC	Consumer credit, total	B168
CCB	Consumer credit, banks	B1622
CMO	Residential mortgage credit, total	B167
CHH	Household credit, total	B166
CCBR	CCB/CPI	
CMOR	CMO/CPI	
CHHR	CHH/CPI	

Financial aggregates
(Quarterly data, seasonally adjusted)

STBCB	Short-term business credit, banks	B461+B488+ B1623
STBC	Short-term business credit, total	B171
TBC	Total business credit	B169
BL	Business loans	B1623
BLBA	Business loans + bankers' acceptances	B1623+B461

Other financial variables
(Quarterly average of monthly observations)

R90	Interest rate on prime 90-day commercial paper	B14017
PMLS	Average resale price, Canadian Real Estate Association	
TSE	Toronto Stock Exchange, month-end closing price	B4237

Not seasonally adjusted

Y_r	GDP, current dollars	D10011
Q_r	GDP, constant dollars	D10031
P_r	GDP deflator	Y_r/Q_r
CPI_r	Consumer price index	D484000
$M1_r$		B2033
$M1R_r$		$M1_r/CPI_r$
CCB_r	Bank consumer credit	B431

Table A1.1
Liquid Assets of Households
Components as per cent of total, total in millions
(End-of-period data)

	71Q4	75Q4	80Q4	85Q4	89Q2
Household deposits	70.7	80.4	88.3	78.2	81.4
CSBs	29.2	19.5	10.5	17.1	10.3
Treasury bills	0.1	0.0	1.1	4.7	8.4
Total	33,921	81,421	166,608	290,067	415,316

Sources: Household deposits: personal chequing accounts (B676) + savings deposits of individuals at banks (B654) + all deposits with trust and mortgage loan companies (B1727) + deposits and capital stock of *caisses populaires* and local credit unions (B3917 + B3919).
CSBs: Canada Savings Bonds (B2406).
Treasury bills: treasury bills, treasury bills held by households (estimation by the Bank of Canada).

Table A1.2
Commercial Bank Loans, Commercial Paper and Bankers' Acceptances
Components as per cent of total, total in millions
(End-of-period data)

	71Q4	75Q4	80Q4	85Q4	89Q2
Commercial loans	90.9	91.6	89.8	80.4	65.5
Commercial paper	6.4	5.0	2.6	3.6	6.4
Bankers' acceptances	2.8	3.4	7.6	16.0	28.1
Total	14,587	30,440	71,005	106,447	151,683

Sources: Commercial loans: commercial loans extended by banks (B1623).
Commercial paper: commercial instruments issued by non-financial corporations (B15020).
Bankers' acceptances: bankers' acceptances (B15011).

Appendix 2

Table A2.1

Quarterly Growth Rates of Nominal GDP, Real GDP, the GDP Deflator, and Various Financial Aggregates

Correlation coefficient over various periods

	Nominal GDP				GDP deflator			
	71Q1-89Q1	71Q1-80Q4	81Q1-89Q1	85Q1-89Q1	71Q1-89Q1	71Q1-80Q4	81Q1-89Q1	85Q1-89Q1
Money								
M1	0.23	0.01	0.17	0.41	0.04	-0.09	-0.22	0.34
M2	0.48	0.39	0.08	0.13	0.60	0.55	0.30	0.35
M2+	0.56	0.43	0.22	0.10	0.59	0.55	0.20	0.44
M3	0.57	0.51	0.18	0.06	0.63	0.62	0.27	0.35
M3+	0.59	0.50	0.24	0.05	0.60	0.60	0.21	0.43
LL	0.49	0.25	0.24	0.38	0.53	0.56	-0.09	0.42
Total credit								
CC	0.50	0.39	0.38	0.27	0.24	0.26	-0.17	-0.09
CMO	0.50	0.41	0.24	0.31	0.24	0.26	-0.32	0.42
CHH	0.53	0.45	0.31	0.36	0.25	0.29	-0.28	0.34
STBC	0.44	0.37	0.18	0.25	0.69	0.65	0.61	0.08
TBC	0.24	0.03	0.20	0.42	0.58	0.42	0.69	0.05
Banks								
CCB	0.52	0.21	0.42	0.47	0.20	0.15	-0.16	0.08
CMOB	0.01	0.12	-0.23	0.21	0.05	-0.27	0.10	0.21
CHHB	0.23	0.18	-0.09	0.36	0.13	-0.23	0.03	0.20
BL	0.40	0.34	0.18	0.08	0.58	0.39	0.60	0.16
TBCB	0.34	0.34	0.12	-0.09	0.56	0.36	0.65	-0.13

(cont'd)

Table A2.1 (cont'd)
Quarterly Growth Rates of Nominal GDP, Real GDP, the GDP Deflator, and Various Financial Aggregates
Correlation coefficient over various periods

	Real GDP*			
	71Q1-89Q1	71Q1-80Q4	81Q1-89Q1	85Q1-89Q1
Money				
M1	0.23 [0.33]	0.10 [0.22]	0.31 [0.42]	0.23 [0.28]
M2	0.02 [0.26]	-0.06 [0.26]	-0.13 [0.20]	-0.06 [0.03]
M2+	0.12 [0.40]	-0.03 [0.35]	0.06 [0.40]	-0.17 [-0.07]
M3	0.10 [0.30]	0.01 [0.30]	-0.03 [0.22]	-0.16 [-0.09]
M3+	0.14 [0.37]	0.02 [0.36]	0.07 [0.35]	-0.22 [-0.14]
LL	0.09 [0.34]	-0.23 [0.09]	0.28 [0.51]	0.14 [0.30]
Total credit				
CC	0.37 [0.51]	0.20 [0.43]	0.46 [0.57]	0.35 [0.38]
CMO	0.36 [0.50]	0.22 [0.44]	0.43 [0.53]	0.06 [0.16]
CHH	0.38 [0.53]	0.23 [0.47]	0.47 [0.57]	0.17 [0.29]
STBC	-0.11 [-0.03]	-0.17 [-0.02]	-0.26 [-0.16]	0.21 [0.27]
TBC	-0.24 [-0.01]	-0.35 [-0.05]	-0.29 [-0.11]	0.42 [0.44]
Banks				
CCB	0.43 [0.54]	0.37 [0.46]	0.49 [0.60]	0.46 [0.51]
CMOB	-0.03 [0.01]	0.37 [0.42]	-0.28 [-0.24]	0.09 [0.15]
CHHB	0.15 [0.25]	0.41 [0.47]	-0.10 [0.03]	0.26 [0.34]
BL	0.06 [0.02]	0.02 [0.19]	-0.25 [-0.18]	-0.02 [0.08]
TBCB	-0.11 [0.05]	0.06 [0.26]	-0.33 [-0.28]	-0.02 [0.02]

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* Correlation with financial aggregate in real terms, i.e., divided by the GDP deflator, in [...].

Table A2.2
Real GDP, GDP Deflator and Nominal GDP
Quarterly growth - correlation coefficients (1972Q1-1988Q2)

Financial aggregate*	Quarters ahead					Quarters behind			
					Real GDP				
	-4	-3	-2	-1	0	1	2	3	4
M1	0.23	0.25	**0.48**	0.42	0.28	0.01	-0.11	-0.24	-0.05
M2	0.02	-0.04	-0.11	0.01	0.20	-0.01	0.15	0.20	**0.27**
M2+	0.11	0.10	0.08	0.19	**0.37**	0.19	0.17	0.21	0.25
M3	-0.06	0.06	-0.02	0.08	0.29	0.25	0.24	**0.31**	0.30
CHH	0.16	0.18	0.26	0.32	**0.54**	0.46	0.38	0.32	0.22
CC	-0.01	0.05	0.21	0.25	0.52	**0.53**	0.41	0.30	0.19
CCB	0.07	0.10	0.27	0.29	**0.51**	0.50	0.39	0.28	0.21
TBC	-0.35	-0.36	**-0.47**	-0.43	-0.11	-0.02	0.13	0.18	0.05
					GDP deflator				
	-4	-3	-2	-1	0	1	2	3	4
M1	0.12	0.07	**0.24**	0.09	0.09	0.05	-0.12	-0.05	0.01
M2	0.45	0.53	**0.71**	0.65	0.66	0.63	0.50	0.38	0.33
M2+	0.52	0.58	**0.72**	0.65	0.63	0.55	0.44	0.32	0.29
M3	0.56	0.50	**0.60**	0.57	0.64	0.57	0.50	0.34	0.20
CHH	**0.49**	0.44	0.40	0.34	0.27	0.17	0.04	-0.07	-0.15
CC	**0.48**	0.43	0.39	0.32	0.24	0.13	0.03	-0.05	-0.11
CCB	**0.49**	0.44	0.39	0.33	0.28	0.19	0.12	0.06	0.04
TBC	0.41	0.45	0.49	0.55	0.56	**0.59**	0.58	0.50	0.40
					Nominal GDP				
	-4	-3	-2	-1	0	1	2	3	4
M1	0.21	0.19	**0.55**	0.41	0.23	0.04	-0.18	-0.24	0.01
M2	0.22	0.22	0.38	0.45	**0.50**	0.47	0.48	0.43	0.49
M2+	0.31	0.34	0.50	0.57	**0.58**	0.54	0.46	0.40	0.47
M3	0.30	0.32	0.38	0.46	**0.59**	0.59	0.55	0.47	0.40
CHH	0.39	0.36	0.44	0.49	**0.55**	0.52	0.36	0.23	0.13
CC	0.25	0.25	0.39	0.42	0.52	**0.55**	0.38	0.22	0.14
CCB	0.35	0.32	0.46	0.46	0.54	**0.55**	0.41	0.27	0.24
TBC	-0.04	-0.04	-0.04	0.08	0.24	0.44	**0.54**	0.52	0.41

* For real GDP growth, correlation coefficients were calculated using real financial aggregates.

Appendix 3

Table A3.1
Estimation Results of Univariate Models
All variables expressed as quarterly growth rates (1972Q1-1989Q2)

		R^2	D.W./D.h.	S.E.E.
GDP				
Current dollars	$Y = 1.076 + 0.595\,Y_{-1}$ $(3.71)\ (6.03)$	0.349	-0.61	0.977
Constant dollars	$Q = 0.628 + 0.326\,Q_{-1}$ $(4.06)\ (2.84)$	0.106	-0.38	0.918
Deflator	$P = 0.300 + 0.446\,P_{-1} + 0.382\,P_{-2}$ $(1.87)\ (3.95)\ (3.43)$	0.594	1.96	0.593
Constant-weight GDP deflator	$FWP = 0.279 + 0.449\,P_{-1} + 0.403\,P_{-2}$ $(1.78)\ (4.01)\ (3.62)$	0.645	1.94	0.555
CPI	$CPI = 0.263 + 0.595\,CPI_{-1} + 0.262\,CPI_{-2}$ $(1.90)\ (5.05)\ (2.23)$	0.685	2.03	0.430
Household expenditures				
Current dollars	$C\$ = 1.249 + 0.186\,C\$_{-1} + 0.346\,C\$_{-2}$ $(3.24)\ (1.62)\ (2.97)$	0.190	2.03	0.888
Constant dollars	$C = 0.658 + 0.096\,C_{-1} + 0.225\,C_{-2}$ $(3.43)\ (0.81)\ (1.92)$	0.069	2.01	0.957
Deflator	$PC = 1.971 + 0.754\,PC_{-1} - 0.769\,PC_{-2}$ $(10.58)\ (8.35)\ (8.48)$	0.648	1.89	0.438

(cont'd)

Table A3.1 (cont'd)
Estimation Results of Univariate Models
All variables expressed as quarterly growth rates (1972Q1-1989Q2)

		$\bar{R}^2$	D.W./D.h.	S.E.E.
Business fixed investment				
Current dollars	$IS\$ = 1.288 + 0.409\ IS\$_{-1} + 0.188\ IS\$_{-2} + 0.061\ IS\$_{-3} - 0.124\ IS\$_{-4}$ (2.48) (3.32) (1.41) (0.46) (1.02)	0.277	1.39	2.866
Constant dollars	$I = 0.956 - 0.421\ I_{-1}$ (2.50) (3.83)	0.177	-1.21	2.817
Deflator	$PI = 0.265 + 0.759\ PI_{-1}$ (2.00) (9.58)	0.575	-1.72	0.848
Housing				
Current dollars	$H\$ = 3.109 + 0.462\ H\$_{-1} - 0.270\ H\$_{-2} + 0.222\ H\$_{-3} - 0.419\ H\$_{-4}$ (4.26) (4.04) (2.15) (1.80) (3.77)	0.317	1.30	4.121
Constant dollars	$H = 1.259 + 0.394\ H_{-1} - 0.281\ H_{-2} + 0.156\ H_{-3} - 0.348\ H_{-4}$ (2.45) (3.37) (2.23) (1.26) (3.03)	0.246	1.96	3.817
Deflator	$PH = 1.026 + 0.405\ PH_{-1} - 0.070\ PH_{-2} + 0.166\ PH_{-3} + 0.246\ PH_{-4}$ (2.75) (3.38) (0.57) (1.38) (2.04)			
	$- 0.293\ PH_{-5}$ (2.55)	0.295	1.92	1.538
Private domestic demand				
Current dollars	$DD\$ = 1.066 + 0.311\ DD\$_{-1} + 0.292\ DD\$_{-2}$ (2.94) (2.66) (2.50)	0.263	1.92	1.117

Table A3.2
Estimation Results of Indicator Models
All variables expressed as quarterly growth rates (1972Q1-1989Q2)

Models without contemporaneous financial aggregates		R^2	D.W.	S.E.E.
GDP, current dollars				
MBY	$Y = \underset{(3.97)}{0.890} + \underset{(4.26)}{0.403}\, Y_{-4} + \underset{(2.83)}{0.152}\, M1_{-1} + \underset{(3.68)}{0.209}\, M1_{-2}$ $\Sigma M1 = \underset{(4.90)}{0.361}$	0.523	2.00	0.849
MMY	$Y = \underset{(3.38)}{0.844} + \underset{(1.87)}{0.201}\, Y_{-1} + \underset{(4.23)}{0.245}\, M1_{-1} + \underset{(5.37)}{0.344}\, M1_{-2} - \underset{(1.00)}{0.009}\, R90_{-1} + \underset{(2.41)}{0.021}\, R90_{-2}$ $+ \underset{(2.84)}{0.025}\, R90_{-3} + \underset{(1.77)}{0.013}\, R90_{-4} + \underset{(2.00)}{0.013}\, R90_{-5} + \underset{(2.00)}{0.014}\, TSE_{-1}$ $\Sigma M1 = \underset{(6.88)}{0.583} \qquad \Sigma R90 = \underset{(3.26)}{0.064}$	0.647	1.75	0.765
C1Y	$Y = \underset{(2.12)}{0.657} + \underset{(4.40)}{0.459} Y_{-1} + \underset{(1.87)}{0.155}\, CMO_{-1} + \underset{(2.38)}{0.040}\, TSE_{-1} + \underset{(1.52)}{0.048}\, PMLS_{-1}$	0.486	1.95	0.888
C2Y	$Y = \underset{(2.08)}{0.643} + \underset{(4.49)}{0.482} Y_{-1} + \underset{(2.14)}{0.191}\, CHH_{-1} + \underset{(3.18)}{0.042}\, TSE_{-1}$	0.462	1.98	0.902
GDP, constant dollars				
MBQ	$Q = \underset{(6.09)}{0.836} + \underset{(0.48)}{0.053}\, Q_{-1} + \underset{(3.54)}{0.168}\, M1R_{-1} + \underset{(3.21)}{0.165}\, M1R_{-2}$ $\Sigma M1R = \underset{(5.22)}{0.334}$	0.367	2.03	0.779

(cont'd)

Table A3.2 (cont'd)
Estimation Results of Indicator Models
All variables expressed as quarterly growth rates (1972Q1-1989Q2)

		$\bar{R}^2$	D.W.	S.E.E.
GDP, constant dollars				
MMQ	$Q = \underset{(5.72)}{0.798} - \underset{(0.01)}{0.001}\,Q_{-1} + \underset{(3.31)}{0.161}\,M1R_{-1} + \underset{(2.30)}{0.119}\,M1R_{-2} + \underset{(0.70)}{0.035}\,M1R_{-3}$			
	$- \underset{(0.24)}{0.012}\,M1R_{-4} + \underset{(2.19)}{0.104}\,M1R_{-5} + \underset{(2.72)}{0.032}\,TSE_{-1}$	0.459	1.81	0.748
	$\Sigma M1R = \underset{(4.81)}{0.408}$			
C1Q	$Q = \underset{(0.84)}{0.232} + \underset{(1.66)}{0.194}\,Q_{-1} + \underset{(1.82)}{0.314}\,CMO_{-1} - \underset{(1.14)}{0.194}\,CMO_{-2} + \underset{(2.88)}{0.037}\,TSE$	0.219	1.94	0.852
	$\Sigma CMO = \underset{(1.65)}{0.120}$			
C2Q	$Q = \underset{(4.74)}{1.367} + \underset{(1.31)}{0.153}\,Q_{-1} + \underset{(0.18)}{0.026}\,TBC_{-1} - \underset{(-1.72)}{0.266}\,TBC_{-2} + \underset{(2.44)}{0.030}\,TSE_{-1}$	0.272	1.96	0.822
	$\Sigma TBC = \underset{(3.08)}{-0.239}$			
GDP deflator				
MBP	$P = \underset{(0.28)}{-0.051} + \underset{(2.49)}{0.283}\,P_{-1} + \underset{(2.16)}{0.242}\,P_{-2} + \underset{(0.91)}{0.073}\,M2_{-1} + \underset{(2.83)}{0.228}\,M2_{-2}$	0.659	1.75	0.552
	$\Sigma M2 = \underset{(3.30)}{0.301}$			

(cont'd)

Table A3.2 (cont'd)

Estimation Results of Indicator Models

All variables expressed as quarterly growth rates (1972Q1-1989Q2)

		$\bar{R}^2$	D.W.	S.E.E.
GDP deflator				
MMP	$P = \underset{(0.28)}{0.053} + \underset{(2.52)}{0.294}\,P_{-1} + \underset{(2.22)}{0.243}\,P_{-2} + \underset{(0.51)}{0.043}\,M2_{-1} + \underset{(2.96)}{0.240}\,M2_{-2}$			
	$+ \underset{(1.00)}{0.006}\,R90_{-1} + \underset{(1.18)}{0.010}\,TSE_{-1}$	0.669	1.80	0.552
	$\Sigma M2 = \underset{(3.05)}{0.282}$			
C1P	$P = \underset{(0.63)}{0.115} + \underset{(3.50)}{0.396}\,P_{-1} + \underset{(3.60)}{0.393}\,P_{-2} + \underset{(1.98)}{0.078}\,CCB_{-1}$	0.617	2.01	0.580
C2P	$P = \underset{(0.57)}{0.104} + \underset{(3.33)}{0.380}\,P_{-1} + \underset{(3.69)}{0.404}\,P_{-2} + \underset{(1.60)}{0.064}\,CCB_{-1} + \underset{(1.12)}{0.022}\,PMLS_{-1}$	0.625	2.03	0.579
Fixed-weight GDP deflator				
MPF	$FWP = \underset{(0.30)}{0.056} + \underset{(2.88)}{0.344}\,FWP_{-1} + \underset{(2.37)}{0.284}\,FWP_{-2} + \underset{(0.92)}{0.075}\,M2_{-1} + \underset{(1.82)}{0.146}\,M2_{-2}$	0.673	1.83	0.541
	$\Sigma M2 = \underset{(2.30)}{0.221}$			
CPI				
MCPI	$CPI = \underset{(0.28)}{-0.037} + \underset{(3.25)}{0.361}\,CPI_{-1} + \underset{(2.44)}{0.246}\,CPI_{-2} + \underset{(1.86)}{0.091}\,M2_{-1} + \underset{(3.16)}{0.171}\,M2_{-2}$	0.775	2.05	0.369

(cont'd)

Table A3.2 (cont'd)
Estimation Results of Indicator Models
All variables expressed as quarterly growth rates (1972Q1-1989Q2)

		R^2	D.W.	S.E.E.
Household expenditures				
Current dollars				
MC$	$C\$ = 0.867 + 0.002\ C\$_{-1} + 0.197\ C\$_{-2} + 0.392\ M2_{-1} - 0.012\ CCB_{-1}$			
	(2.34) (0.13) (1.62) (3.26) (0.13)			
	$- 0.013\ CCB_{-2} + 0.168\ CCB_{-3} - 0.168\ CCB_{-4}$	0.370	1.98	0.814
	(1.23) (1.67) (1.61)			
	$\Sigma CCB = 0^*$			
Constant dollars				
MC	$C = 1.160 - 0.297\ C_{-1} + 0.206\ C_{-2} - 0.097\ M1R_{-1} + 0.077\ M1R_{-2}$			
	(5.19) (2.20) (0.16) (1.48) (1.24)			
	$+ 0.092\ M1R_{-3} + 0.083\ M1R_{-4} + 0.133\ M1R_{-5} + 0.034\ TSE_{-1}$			
	(1.61) (1.36) (2.40) (2.61)			
	$+ 0.019\ TSE_{-2} - 0.006\ TSE_{-3} - 0.030\ TSE_{-4} - 0.017\ TSE_{-5}$	0.427	2.01	0.814
	(1.42) (-0.43) (2.15) (1.15)			
	$\Sigma M1R = 0.482$ (4.06) $\Sigma TSE = 0.001$ (0.05)			
Deflator				
MPC	$PC = -0.061 + 0.396\ PC_{-1} + 0.235\ PC_{-2} + 0.146\ {}^*M2_{-1} + 0.096\ M2_{-2}$	0.776	2.16	0.354
	(0.48) (3.37) (2.27) (3.11) (1.79)			

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* Constraint of zero sum imposed.

(cont'd)

Table A3.2 (cont'd)

Estimation Results of Indicator Models

All variables expressed as quarterly growth rates (1972Q1-1989Q2)

Business fixed investment		$\bar{R}^2$	D.W.	S.E.E.
Current dollars				
MI\$	$IS = \underset{(0.37)}{0.248} + \underset{(2.79)}{0.344}\,IS_{-1} + \underset{(1.27)}{0.166}\,IS_{-2} + \underset{(0.36)}{0.049}\,IS_{-3} - \underset{(-0.35)}{0.044}\,IS_{-4}$			
	$+ \underset{(1.35)}{0.249}\,M1_{-1} + \underset{(1.78)}{0.318}\,M1_{-2}$	0.338	1.94	2.786
	$\Sigma M1 = \underset{(2.38)}{0.567}$			
Constant dollars				
MI	$I = \underset{(2.91)}{1.072} + \underset{(2.63)}{0.359}\,I_{-1} + \underset{(2.69)}{0.5087}\,STBCB_{-1} - \underset{(2.69)}{0.5087}\,STBCB_{-2}$	0.258	2.03	2.697
	$\Sigma STBCB = 0$[a]			
Deflator				
MPI	$PI = \underset{(2.52)}{-0.733} + \underset{(6.97)}{0.532}\,PI_{-1} + \underset{(3.77)}{0.379}\,M2P_{-1}$	0.649	2.24	0.776
Housing				
Current dollars				
MH\$	$H\$ = \underset{(1.54)}{1.402} + \underset{(3.29)}{0.373}\,H\$_{-1} - \underset{(2.93)}{0.371}\,H\$_{-2} + \underset{(1.20)}{0.159}\,H\$_{-3} - \underset{(2.75)}{0.310}\,H\$_{-4}$			
	$+ \underset{(1.37)}{0.387}\,M1_{-1} + \underset{(2.51)}{0.724}\,M1_{-2}$	0.404	1.90	3.910
	$\Sigma M1 = \underset{(2.95)}{1.111}$			

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[a] Constraint of zero sum imposed.

(cont'd)

Table A3.2 (cont'd)
Estimation Results of Indicator Models
All variables expressed as quarterly growth rates (1972Q1-1989Q2)

		$\bar{R}^2$	D.W.	S.E.E.
Housing				
Constant dollars				
MH	$H = \underset{(2.22)}{1.214} + \underset{(3.48)}{0.455^{*}}H_{-1} - \underset{(2.74)}{0.382^{*}}H_{-2} + \underset{(1.89)}{0.262}\,H_{-3} - \underset{(3.17)}{0.381}\,H_{-4} + \underset{(0.82)}{0.408}\,M2R_{-1}$			
	$-\underset{(0.84)}{0.473}\,M2R_{-2} - \underset{(0.81)}{0.423}\,M2R_{-3} + \underset{(0.72)}{0.373}\,M2R_{-4} + \underset{(2.00)}{1.050}\,M2R_{-5} - \underset{(-)}{0.065}\,M2R_{-6}$			
	$-\underset{(0.015)}{0.010}\,TSE_{-1} + \underset{(2.22)}{0.140}\,TSE_{-2} - \underset{(1.33)}{0.085}\,TSE_{-3}$	0.414	1.86	3.594
	$\Sigma M2R = 0^{*} \qquad \Sigma TSE = \underset{(0.47)}{0.046}$			
Deflator				
MPH	$PH = \underset{(1.52)}{0.626} + \underset{(2.64)}{0.326}\,PH_{-1} - \underset{(0.79)}{0.098}\,PH_{-2} + \underset{(1.25)}{0.149}\,PH_{-3} + \underset{(2.16)}{0.261}\,PH_{-4} - \underset{(-2.21)}{0.255}\,PH_{-5}$			
	$+\underset{(1.44)}{0.141}\,M1_{-1} + \underset{(1.36)}{0.135}\,M1_{-2}$	0.343	1.98	1.508
Private domestic demand				
Current dollars				
MDD\$	$DD\$ = \underset{(1.16)}{0.447} + \underset{(0.97)}{0.116}\,DD\$_{-1} + \underset{(1.97)}{0.237}\,DD\$_{-2} + \underset{(2.60)}{0.388}\,M2P_{-1} + \underset{(2.73)}{0.043}\,{}^{*}TSE_{-1}$	0.403	2.09	1.02

* Constraint of zero sum imposed.

Table A3.3
Estimation Results of Indicator Models
All variables expressed as quarterly growth rates (1972Q1-1989Q2)

	Model with contemporaneous financial aggregates	$\bar{R}^2$	D.W.	S.E.E.
GDP, current dollars				
BMBY	$Y = 0.149 + 0.137\,Y_{-1} + 0.148\,M1_{-1} + 0.298\,M1_{-2} + 0.447\,M2_{0}$ (0.58) (1.44) (3.27) (5.86) (5.24)	0.665	1.71	0.717
	$\Sigma M1 = 0.446$ (6.93)			
BMMY	$Y = 0.160 + 0.168\,Y_{-1} + 0.135\,M1_{-1} + 0.282\,M1_{-2} + 0.018\,TSE_{-1} + 0.420\,M2_{0}$ (0.63) (1.77) (2.98) (3.53) (1.69) (4.83)	0.679	1.68	0.707
	$\Sigma M1 = 0.417$ (6.34)			
BC1Y	$Y = 0.599 + 0.470\,Y_{-1} + 0.224\,CMO_{0}$ (1.84) (4.50) (2.77)	0.416	2.00	0.933
BC2Y	$Y = 0.635 + 0.442\,Y_{-1} + 0.253\,CHH_{0}$ (2.00) (4.06) (2.79)	0.416	1.99	0.932
GDP, constant dollars				
BMBQ	$Q = 0.747 - 0.056\,Q_{-1} + 0.134\,M1R_{-1} + 0.145\,M1R_{-2} + CCBR_{0}$ (5.38) (-0.48) (2.81) (2.86) (2.41)	0.416	1.85	0.753
	$\Sigma M1R = 0.279$ (4.25)			

(cont'd)

Table A3.3 (cont'd)
Estimation Results of Indicator Models
All variables expressed as quarterly growth rates (1972Q1-1989Q2)

		R^2	D.W.	S.E.E.
GDP, constant dollars				
BMMQ	$Q = 0.697 - 0.046\ Q_{-1} + 0.120\ M1R_{-1} + 0.132\ M1R_{-2} + 0.008\ R90_{-1}$ (4.37) (0.38) (2.50) (2.45) (0.10) $+ 0.024\ TSE_{-1} + 0.136\ CCBR_0$ (2.04) (2.23) $\Sigma M1R = 0.253$ (3.71)	0.454	1.86	0.745
BC1Q	$Q = 0.397 + 0.015\ Q_{-1} + 0.682\ CHH_0 - 0.177\ CHH_{-1} + 0.154\ CHH_{-2}$ (1.54) (0.12) (4.10) (0.82) (0.71) $- 0.504\ CHH_{-3}$ (3.09) $\Sigma CHH = 0.155$ (2.01)	0.371	2.00	0.794
BC2Q	$Q = 0.573 - 0.020\ Q_{-1} + 0.468\ CC_0 - 0.135\ CC_{-1} + 0.173\ CC_{-2} - 0.386\ CC_{-3}$ (2.42) (0.16) (3.81) (1.01) (1.29) (3.58) $\Sigma CC = 0.119$ (1.49)	0.357	2.08	0.803
GDP deflator				
BMBP	$P = 0.045 + 0.210\ P_{-1} +$ 0.[illegible]50 $P_{-2} - 0.039\ M2_{-1} + 0.236\ M2_{-2} + 0.146\ M3_0$ (0.26) (1.88) (2.38) (0.46) (3.11) (3.09) $\Sigma M2 = 0.197$ (2.13)	0.703	1.62	0.519

(cont'd)

Table A3.3 (cont'd)
Estimation Results of Indicator Models
All variables expressed as quarterly growth rates (1972Q1-1989Q2)

		R^2	D.W.	S.E.E.
GDP deflator				
BMMP	$P = \underset{(0.35)}{-0.063} + \underset{(1.95)}{0.222}\,P_{-1} + \underset{(2.39)}{0.254}\,P_{-2} - \underset{(0.59)}{0.050}\,M2_{-1} + \underset{(3.16)}{0.243}\,M2_{-2} + \underset{(0.28)}{0.001}\,R90_{-1}$			
	$+ \underset{(0.90)}{0.007}\,TSE_{-1} + \underset{(2.83)}{0.140}\,M3_0$	0.707	1.66	0.524
	$\Sigma M2 = \underset{(2.06)}{0.192}$			
BC1P	$P = \underset{(2.25)}{0.350} + \underset{(3.15)}{0.359}\,P_{-1} + \underset{(3.01)}{0.323}\,P_{-2} + \underset{(2.52)}{0.064}\,BL_0$	0.630	1.97	0.571
BC2P	$P = \underset{(2.17)}{0.332} + \underset{(2.58)}{0.308}\,P_{-1} + \underset{(2.72)}{0.301}\,P_{-2} + \underset{(2.68)}{0.096}\,STBC_0$	0.634	1.97	0.567
Household expenditures				
Current dollars				
BMC\$	$C\$ = \underset{(1.97)}{0.729} + \underset{(0.03)}{0.028}\,C\$_{-1} + \underset{(2.21)}{0.239}\,C\$_{-2} + \underset{(4.05)}{0.418}\,M2P_0$	0.351	2.04	0.801
Constant dollars				
BMC	$C = \underset{(4.41)}{0.692} - \underset{(1.52)}{0.185}\,C_{-1} + \underset{(4.12)}{0.636}\,CHHR_0 - \underset{(0.34)}{0.070}\,CHHR_{-1} - \underset{(1.64)}{0.257}\,CHHR_{-2}$	0.319	2.04	0.831
	$\Sigma CHHR = \underset{(4.10)}{0.311}$			

(cont'd)

Table A3.3 (cont'd)
Estimation Results of Indicator Models
All variables expressed as quarterly growth rates (1972Q1-1989Q2)

		R^2	D.W.	S.E.E.
Household expenditures				
Deflator				
BMPC	$PC = \underset{(0.52)}{0.071} + \underset{(3.28)}{0.392}\ {}^{*}PC_{-1} + \underset{(2.26)}{0.238}\ PC_{-2} + \underset{(0.22)}{0.010}\ M2_0 - \underset{(2.54)}{0.140}\ M2_{-2} + \underset{(1.75)}{0.095}\ M2_{-2}$	0.777	2.15	0.357
	$\Sigma M2 = \underset{(4.66)}{0.245}$			
Business fixed investment				
Current dollars				
BMI$	$I\$ = \underset{(0.09)}{0.072} + \underset{(2.64)}{0.332}\ I\$_{-1} + \underset{(1.27)}{0.166}\ I\$_{-2} + \underset{(0.50)}{0.064}\ I\$_{-3} - \underset{(0.36)}{0.045}\ I\$_{-4}$			
	$+ \underset{(0.51)}{0.095}\ M1_0 + \underset{(1.25)}{0.233}\ M1_{-1} + \underset{(1.79)}{0.322}\ M1_{-2}$	0.340	1.94	2.083
	$\Sigma M1 = \underset{(2.24)}{0.650}$			
Constant dollars				
BMI	$I = \underset{(0.84)}{0.803} + \underset{(1.46)}{0.214}\ I_{-1} + \underset{(1.75)}{0.563}\ M2_0 + \underset{(0.39)}{0.244}\ BLBA_0 + \underset{(0.61)}{0.188}\ BLBA_{-1}$			
	$- \underset{(-1.83)}{0.570}\ BLBA_{-2} - \underset{(-)}{0.425}\ BLBA_{-3} + \underset{(1.80)}{0.081}\ {}^{*}TSE_0 + \underset{(0.74)}{0.037}\ TSE_{-1}$			
	$+ \underset{(0.90)}{0.042}\ TSE_{-2} - \underset{(-0.26)}{0.125}\ TSE_{-3}$	0.421	2.01	2.678
	$\Sigma TSE = \underset{(2.15)}{0.197}$			

(cont'd)

Table A3.3 (cont'd)
Estimation Results of Indicator Models
All variables expressed as quarterly growth rates (1972Q1-1989Q2)

		$\bar{R}^2$	D.W.	S.E.E.
Business fixed investment				
Deflator				
BMPI	$PI = \underset{(2.40)}{0.340} + \underset{(9.03)}{0.736}\, PI_{-1} + \underset{(1.36)}{0.105}\, STBC_0 - 0.105\, STBC_{-1} - \underset{(1.59)}{0.021}\, TSE_0$	0.601	2.46	0.833
Housing				
Current dollars				
BMH$	$H\$ = \underset{(0.50)}{0.472} + \underset{(2.26)}{0.263}\, H\$_{-1} - \underset{(1.84)}{0.240}\, H\$_{-2} + \underset{(1.32)}{0.167}\, H\$_{-3} - \underset{(3.23)}{0.352}\, H\$_{-4} + \underset{(2.62)}{0.703}\, M1_0$			
	$+ \underset{(0.94)}{0.259}\, M1_{-1} + \underset{(2.43)}{0.671}\, M1_{-2}$	0.464	1.89	3.739
	$\Sigma M1 = \underset{(3.96)}{1.632}$			
Constant dollars				
BMH	$H = \underset{(2.99)}{1.418} + \underset{(0.81)}{0.119}\, H_{-1} - \underset{(1.52)}{0.213}\, H_{-2} + \underset{(0.18)}{0.023}\, H_{-3} - \underset{(2.11)}{0.264}\, H_{-4} + \underset{(1.35)}{0.377}\, M1R_0$			
	$+ \underset{(0.11)}{0.032}\, M1R_{-1} + \underset{(1.45)}{0.426}\, M1R_{-2} + \underset{(0.78)}{0.220}\, M1R_{-3} - \underset{(1.01)}{0.274}\, M1R_{-4} + \underset{(1.42)}{0.339}\, M1R_{-5}$			
	$+ \underset{(1.79)}{1.311}\, CMOR_0 + \underset{(0.73)}{0.740}\, CMOR_{-1} - \underset{(1.71)}{1.753}\, CMOR_{-2} - \underset{(1.28)}{1.297}\, CMOR_{-3}$	0.571	2.01	3.159
	$+ \underset{(1.12)}{1.1068}\, CMOR_{-4} - 0.1078\, CMOR_{-5}$			
	$\Sigma M1R = \underset{(2.75)}{1.121}$			

(cont'd)

Table A3.3 (cont'd)
Estimation Results of Indicator Models
All variables expressed as quarterly growth rates (1972Q1-1989Q2)

		$\bar{R}^2$	D.W.	S.E.E.
Housing **Deflator** **BMPH**	$PH = \underset{(0.13)}{0.069} + \underset{(2.62)}{0.360}\,PH_{-1} - \underset{(2.03)}{0.288}\,PH_{-2} + \underset{(2.07)}{0.270}\,PH_{-3} + \underset{(0.45)}{0.062}\,PH_{-4} - \underset{(1.42)}{0.1877}\,PH_{-4}$			
	$- \underset{(0.44)}{0.013}\,TSE_0 - \underset{(0.16)}{0.005}\,TSE_{-1} + \underset{(0.35)}{0.010}\,TSE_{-2} - \underset{(0.61)}{0.019}\,TSE_{-3} - \underset{(0.95)}{0.029}\,TSE_{-4}$			
	$+ \underset{(2.14)}{0.065}\,TSE_{-5} + \underset{(0.02)}{0.001}\,TSE_{-6} + \underset{(2.02)}{0.059}\,TSE_{-7}$	0.542	2.02	1.478
	$\Sigma M1 = \underset{(3.41)}{0.428} \qquad \Sigma TSE = \underset{(1.50)}{0.107}$			
Private domestic demand **Current dollars** **BMDD\$**	$DD\$ = \underset{(1.42)}{0.515} + \underset{(1.09)}{0.133}\,DD\$_{-1} + \underset{(2.95)}{0.349}\,DD\$_{-2} + \underset{(2.92)}{0.210}\,M_{-1} + \underset{(0.84)}{0.061}\,M1_{-2}$	0.485	1.97	1.00
	$\Sigma M1 = \underset{(3.41)}{0.428}$			

Table A3.4
Indicator Models Using the Change of the Rate of Growth of Credit Aggregates
(Goal variable: GDP in constant dollars)

	Model without contemporaneous financial aggregates		Model with contemporaneous financial aggregates	
	72Q1-79Q4	72Q1-89Q1	72Q1-79Q4	72Q1-89Q1
Constant	1.079 (4.17)	0.889 (5.93)	1.294 (4.61)	1.033 (6.73)
Q_{-1}	-0.093 (0.47)	0.020 (0.16)	-0.231 (1.05)	-0.110 (0.83)
$M1R_{-1}$	0.171 (1.90)	0.197 (3.57)	0.164 (1.64)	0.190 (3.33)
$M1R_{-2}$	0.104 (1.04)	0.101 (1.68)	0.074 (0.73)	0.087 (1.99)
ΔCCB_0	-	-	0.221 (1.49)	0.238 (2.98)
ΔCCB_{-1}	-0.278 (1.84)	-0.014 (0.15)	-0.152 (0.89)	0.058 (0.57)
ΔCCB_{-2}	0.022 (0.14)	0.194 (1.99)	0.080 (0.47)	0.217 (2.17)
ΔCCB_{-3}	0.42 (0.29)	0.151 (1.68)	0.082 (0.52)	0.142 (1.55)
$\Delta STBCB_0$	-	-	0.141 (1.15)	0.099 (1.18)
$\Delta STBCB_{-1}$	-	-	0.066 (0.51)	0.068 (0.80)
$\Delta STBCB_{-2}$	-	-	-0.154 (1.38)	-0.028 (0.38)
$\bar{R}^2$	0.18	0.36	0.21	0.43
D.W.	1.86	1.97	1.91	2.03
$\Sigma M1R$	0.278 (2.32)	0.299 (4.22)	0.238 (1.30)	0.276 (3.88)
$\Sigma \Delta CCB$	-0.215 (0.630)	0.331 (1.59)	0.230 (0.49)	0.655 (2.56)
$\Sigma \Delta STBCB$	-	-	0.053 (0.26)	0.139 (1.04)

Appendix 4

Table A4.1
Explanatory Notes for Forecast Evaluation Tables

ſ - correlation coefficient between historical series X and the forecast of this series XP.

ME - mean error $\Sigma(X\text{-}XP)/n$, where n is the number of quarters for which forecasts were made.

MAE - mean absolute error, $\Sigma|(X\text{-}XP)|/n$.

RMSE - root-mean-square error, $\surd(\Sigma(X\text{-}XP)^2/n)$.

PM - ratio of variance of error (var_e) to variance of the historical series (var_x), $PM = var_e/var_x$.

Maximum error - largest forecast error in the period under study.

UM - contribution of systematic bias to forecast error,
$UM = ((\Sigma XP/n)\text{-}(\Sigma X/n))/D^2\ D^2_N = (1/n)^*\Sigma(X\text{-}XP)^2$.

UR - contribution of variance to error, $UR = (s_{XP}\text{-}ſ^* s_X)^2/D^2_N$.

UD - 1-UM-UR (see Granger and Newbold, p. 288, 1977).

α,β - econometric estimates of coefficients of an equation linking the historical series to the forecast values, $X = \alpha + \beta\ ^*\ XP + \mu$. When the results are followed by a " + ", this indicates that the D.W. statistic suggests the presence of autocorrelation.

δ - econometric estimate of the slope coefficient of an equation linking the forecast error to its past value, $(X\text{-}XP) = \pi + \delta\ ^*\ (X\text{-}XP)_{-1} + \mu$.

Q2, Q4, Q6, Q8 - are the values of the Ljung-Box-Pierce statistic to test for the presence of autocorrelation in forecast errors for 2, 4, 6, and 8 lags. Q is approximately distributed according to χ^2 with the following critical values at 5 per cent: 5.991 for 2 lags, 9.488 for 4 lags, 12.592 for 6 lags and 15.507 for 8 lags. Estimated values below these critical values indicate that the hypothesis of the absence of autocorrelation cannot be rejected. $Q = n(n+2)^*\ \Sigma^i_k(n - k)^{-1*}r^2_k$, $i = 2, 4, 6$, and 8, respectively, and r_k is the

(cont'd)

Table A4.1 (cont'd)
Explanatory Notes for Forecast Evaluation Tables

Q2, Q4, Q6, Q8	- correlation coefficient between the forecast error e at time t and t-k ($r_k = \text{cov}(e_t,e_{t-1})/\text{var}(e_t)$). (See Zarnowitz, 1985.)
Inv. \$, Trade, Oil	- are additional variables used in an equation linking the historical series to the forecast values, $X = a0 + a1 * XP + a2 \text{ Inv. \$} + a3 \text{ Trade} + a4 * \text{oil} + b$. The following symbols are used to indicate whether the variables are statistically significant when these equations are estimated: ** significant at 5 per cent; * significant at 10 per cent, = significant at 20 per cent, ! not significant. For models of nominal macroeconomic aggregates, the nominal variation in inventories (as a percentage of nominal GDP in the previous quarter), the variation of the nominal trade balance (as a percentage of nominal GDP in the previous quarter) and the growth rate of oil prices, were used. For deflator models, the growth rates of deflators for inventories and the trade balance, as well as the growth rate of oil prices, were used. Finally, for real macroeconomic aggregates, the variation in inventories (in real terms) and the trade balance (in real terms), both expressed as a percentage of real GDP in the previous quarter, as well as the growth rate of the oil price, were used (see Appendix 1 for precise definitions and data sources).
N	- is the success rate (%) of the forecast of the direction of change in the growth rate of the goal variable.
NG	- is the success rate (%) of the forecast of the direction of change in the growth rate of the goal variable when the actual variation exceeds the standard deviation of the variation in the growth rate of the goal variable during the 1970s. (Table A4.2 gives the frequency of such changes in the growth rates of goal variables during the 1980s.)
NPT	- is the number of accurately predicted turning points, i.e., the number of times the forecast correctly predicted a change of sign in the growth rate of the goal variable. (Table A4.2 gives the actual number of turning points in the 1980s for each goal variable.)
NFS	- is the number of false signs, i.e., the number of times the forecast indicated that the growth rate of the goal variable would change in sign and this did not actually occur.

Table A4.2
Acceleration, Deceleration and Sign Changes in the Growth of Goal Variables (1980Q1-1989Q2)

	Number of accelerations and decelerations			
	Total number	Standard deviation of variation in growth*	Number of one-time variations exceeding one standard deviation	Number of changes in the sign of growth rate
Y	37	1.36	5	0
P	37	0.84	2	0
Q	37	1.39	5	4
FWP	37	0.77	4	0
CPI	37	0.52	6	0
C$	37	1.52	4	0
PC	37	0.47	8	0
C	37	1.65	4	4
H$	37	5.64	13	6
PH	37	2.68	1	3
H	37	5.15	13	16
I$	37	3.47	0	10
PI	37	0.75	15	11
I	37	3.37	18	16
DD$	37	1.76	3	2
PDD	37	0.46	5	0
DD	37	1.82	4	4

* The standard deviation of the change in the growth rate of the goal variable was calculated for the period 1970Q1-1979Q4.

Table A4.3
Composite Models

Nominal GDP

M1Y = MBQ + MBP
M2Y = MMQ + MMP
M3Y = MBQ + MMP
M4Y = MBQ + MBP
MC3Y = C1Q + C1P
MC4Y = C2Q + C2P
MC5Y = C1Q + C2P
MC6Y = C2Q + C1P

MI1Y = MBQ + C1P
MI2Y = MBQ + C2P
MI3Y = MMQ + C1P
MI4Y = MMQ + C2P
MI5Y = C1Q + MBP
MI6Y = C1Q + MMP
MI7Y = C2Q + MBP
MI8Y = C2Q + MMP

COM1Y = 0.36 *MBY + 0.64 M3Y
COM2Y = 0.65 *M1Y + 0.35 M3Y

Table A4.4
Evaluation of Current-Quarter Forecasts of Growth in Nominal GDP (1980Q2-1989Q2)

	Model:					
	BMY	**MMY**	**M1Y**	**M2Y**	**M3Y**	**M4Y**
Forecast						
Average historical growth rate	2.12	2.12	2.12	2.12	2.12	2.12
Average projected growth rate	2.38	2.23	2.28	2.32	2.29	2.32
Correlation of historical & projected growth rate	0.64	0.55	0.67	0.62	0.68	0.61
Forecast error						
ME	-0.26	-0.11	-0.17	-0.21	-0.17	-0.20
MAE	0.59	0.63	0.60	0.66	0.60	0.63
RMSE	0.81	0.86	0.74	0.88	0.77	0.81
Maximum error	2.36	2.57	1.59	1.85	1.51	2.25
PM	0.64	0.80	0.56	0.80	0.62	0.66
UM	0.11	0.02	0.05	0.06	0.05	0.06
UR	0.07	0.13	0.01	0.22	0.12	0.06
UD	0.83	0.85	0.94	0.72	0.83	0.88
α	0.30	0.71+	0.02+	0.50	0.29	0.25+
	(0.78)	(1.83)	(0.04)	(1.52)	(0.88)	(0.61)
β	0.75	0.63+	0.93+	0.71	0.82	0.81+
	(4.89)	(3.85)	(5.27)	(5.19)	(5.34)	(4.69)
δ	0.21	0.30	0.36	0.22	0.22	0.36
	(1.27)	(1.80)	(2.20)	(1.48)	(1.42)	(2.23)
Q2	3.51	0.54	2.07	1.68	2.07	1.40
Q4	4.61	0.67	3.53	2.04	2.66	2.49
Q6	4.78	5.44	4.72	2.62	3.33	2.77
Q8	5.62	7.57	8.76	5.83	6.90	5.07
Inv.$	**	**	**	**	**	**
Trade balance	**	**	**	**	**	**
Oil	*	=	=	=	=	=
Forecast of the sign of the change in the growth rate						
N	0.51	0.40	0.57	0.57	0.65	0.57
NG	0.20	0.20	0.20	0	0.20	0.20
NTP	-	-	-	-	-	-
NFS	0	0	0	2	0	0

(cont'd)

Table A4.4 (cont'd)
Evaluation of Current-Quarter Forecasts of Growth in Nominal GDP (1980Q2-1989Q2)

	Model: C1Y	C2Y	C3Y	C4Y	C5Y	C6Y
Forecast						
Average historical growth rate	2.12	2.12	2.12	2.12	2.12	2.12
Average projected growth rate	2.41	2.27	2.15	2.55	2.21	2.49
Correlation of historical & projected growth rate	0.47	0.44	0.50	0.57	0.57	0.48
Forecast error						
ME	-0.30	-0.16	-0.03	-0.44	-0.09	-0.37
MAE	0.81	0.73	0.69	0.75	0.69	0.73
RMSE	1.02	0.96	0.86	0.94	0.85	0.94
Maximum error	2.31	2.80	1.97	1.34	1.99	2.18
PM	1.05	0.97	0.81	0.74	0.78	0.81
UM	0.08	0.03	0.01	0.22	0.01	0.16
UR	0.24	0.16	0.08	0.07	0.14	0.04
UD	0.68	0.81	0.92	0.71	0.85	0.80
α	0.95+	0.92+	0.60+	0.36+	0.70	0.32+
	(2.43)	(2.05)	(1.30)	(0.79)	(1.85)	(0.55)
β	0.47+	0.53+	0.71+	0.69+	0.65	0.72
	(3.06)	(2.80)	(3.41)	(4.01)	(4.03)	(3.18)+
δ	0.41	0.39	0.24	0.54	0.19	0.52
	(2.52)	(2.40)	(1.39)	(3.72)	(1.08)	(3.50)
Q2	2.19	1.10	0.45	7.22	0.08	5.18
Q4	4.60	2.25	6.04	7.62	0.73	5.80
Q6	10.18	7.48	9.90	12.74	2.31	11.89
Q8	12.17	8.70	19.11	38.55	8.13	34.19
Inv.$	**	**	**	**	**	**
Trade balance	**	**	**	**	**	**
Oil	**	**	**	**	**	*
Forecast of the sign of the change in the growth rate						
N	0.57	0.49	0.43	0.62	0.51	0.59
NG	0	0	0	0.20	0.20	0
NTP	-	-	-	-	-	-
NFS	2	0	0	0	0	0

(cont'd)

Table A4.4 (cont'd)
Evaluation of Current-Quarter Forecasts of Growth in Nominal GDP (1980Q2-1989Q2)

	Model: M11Y	M12Y	M13Y	M14Y	M15Y
Forecast					
Average historical growth rate	2.12	2.12	2.11	2.12	2.12
Average projected growth rate	2.25	2.31	2.29	2.35	2.17
Correlation of historical & projected growth rate	0.74	0.75	0.73	0.74	0.44
Forecast error					
ME	-0.14	-0.20	-0.17	-0.23	-0.06
MAE	0.51	0.51	0.52	0.56	0.75
RMSE	0.67	0.67	0.68	0.70	0.95
Maximum error	1.57	1.59	2.09	1.11	1.99
PM	0.46	0.44	0.47	0.48	0.97
UM	0.04	0.09	0.07	0.11	0
UR	0.01	0.02	0	0.04	0.17
UD	0.95	0.89	0.93	0.85	0.83
α	-0.34	0.07	-0.37	0.14+	0.85+
	(0.86)	(0.21)	(0.91)	(0.44)	(1.90)
β	1.09	0.88	1.09	0.84+	0.59+
	(6.35)	(6.72)	(6.31)	(6.33)	(2.96)
δ	0.35	0.18	0.40	0.35	0.33
	(2.12)	(0.03)	(2.51)	(2.09)	(2.06)
Q2	0.69	0	0.45	0.48	2.49
Q4	4.24	2.40	2.85	1.03	4.22
Q6	6.60	2.41	4.82	1.73	6.71
Q8	11.00	6.59	7.65	6.21	15.65
Inv.$	**	**	**	*	**
Trade balance	**	*	**	**	**
Oil	=	*	=	*	**
Forecast of the sign of the change in the growth rate					
N	0.68	0.59	0.59	0.65	0.51
NG	0	0.20	0	0.20	0
NTP	-	-	-	-	-
NFS	0	0	0	2	0

(cont'd)

Table A4.4 (cont'd)
Evaluation of Current-Quarter Forecasts of Growth in Nominal GDP (1980Q2-1989Q2)

	Model: M16Y	M17Y	M18Y	COM1Y	COM2Y
Forecast					
Average historical growth rate	2.12	2.12	2.12	2.12	2.12
Average projected growth rate	2.18	2.52	2.53	2.32	2.28
Correlation of historical & projected growth rate	0.48	0.44	0.48	0.70	0.68
Forecast error					
ME	-0.07	-0.40	-0.41	-0.21	-0.17
MAE	0.77	0.80	0.82	0.57	0.59
RMSE	1.02	0.99	1.05	0.74	0.73
Maximum error	1.91	2.34	1.94	1.81	1.56
PM	1.11	0.88	1.00	0.54	0.55
UM	0.04	0.17	0.15	0.08	0.05
UR	0.32	0.07	0.21	0.05	0.03
UD	0.68	0.76	0.64	0.87	0.32
α	0.90+ (2.49)	0.43+ (0.74)	0.60+ (1.34)	0.19 (0.53)	0.08 (0.22)
β	0.70+ (3.63)	0.67 (2.97)	0.61 (3.37)+	0.84 (3.84)	0.90 (5.61)
δ	0.21 (1.36)	0.51 (3.46)	0.37 (2.52)	0.21 (1.26)	0.31 (1.93)
Q2	0.89	5.57	3.36	2.22	1.78
Q4	0.96	5.63	3.64	2.88	2.75
Q6	2.97	13.63	6.71	3.53	3.02
Q8	9.22	35.27	26.50	3.05	6.68
Inv.$	**	**	**	**	**
Trade balance	**	**	**	**	**
Oil	**	=	*	=	=
Forecast of the sign of the change in the growth rate					
N	0.51	0.46	0.51	0.57	0.59
NG	0	0	0	0.20	0.40
NTP	-	-	-	-	-
NFS	0	0	0	0	0

Table A4.5
Evaluation of One-Quarter-Ahead Forecasts of Current Dollar GDP Growth
(1980Q2-1989Q2)

	Average growth rate: Historical	Predicted	r	ME	MAE	RMSE	Maximum error	PM	N	NG	NPT	NFS
BMY	2.12	2.49	0.53	-0.37	0.69	0.93	2.37	0.79	0.57	0.20	-	0
MMY	2.12	2.25	0.53	-0.13	0.65	0.89	2.56	0.89	0.43	0.20	-	0
M1Y	2.12	2.32	0.63	-0.39	0.63	0.78	1.59	0.61	0.62	0	-	0
M2Y	2.12	2.38	0.61	-0.45	0.69	0.93	1.57	0.87	0.62	0.40	-	0
M3Y	2.12	2.33	0.64	-0.21	0.62	0.85	1.59	0.73	0.59	0.40	-	0
M4Y	2.12	2.36	0.61	-0.25	0.63	0.82	1.96	0.66	0.54	0	-	0
C1Y	2.12	2.49	0.31	-0.38	0.97	1.21	2.75	1.44	0.59	0	-	2
C2Y	2.12	2.32	0.19	-0.20	0.90	1.16	3.46	1.43	0.54	0	-	0
C3Y	2.12	2.22	0.33	-0.11	0.78	0.97	2.22	1.00	0.57	0	-	0
C4Y	2.12	2.67	0.52	-0.56	0.87	1.07	1.51	0.90	0.65	0.20	-	0
C5Y	2.12	2.31	0.47	-0.19	0.79	0.34	2.02	0.93	0.59	0.20	-	0
C6Y	2.12	2.59	0.41	-0.47	0.83	1.04	1.90	0.93	0.65	0	-	0
MI1Y	2.12	2.30	0.68	-0.18	0.55	0.72	1.87	0.53	0.62	0	-	0
MI2Y	2.12	2.38	0.72	-0.27	0.53	0.73	1.67	0.51	0.68	0.20	-	0
MI3Y	2.12	2.34	0.70	-0.22	0.56	0.72	1.79	0.51	0.65	0	-	0
MI4Y	2.12	2.42	0.71	-0.31	0.61	0.78	1.26	0.57	0.68	0.40	-	0
MI5Y	2.12	2.25	0.30	-0.13	0.87	1.05	2.15	1.18	0.49	0	-	0
MI6Y	2.12	2.25	0.38	-0.14	0.90	1.14	1.94	1.38	0.54	0	-	0
MI7Y	2.12	2.61	0.42	-0.50	0.88	1.06	2.07	0.96	0.51	0	-	0
MI8Y	2.12	2.62	0.47	-0.50	0.90	1.15	1.68	1.15	0.59	0.20	-	0
COM1Y	2.12	2.39	0.64	-0.27	0.61	0.81	1.87	0.64	0.59	0.40	-	0
COM2Y	2.12	2.15	0.64	-0.21	0.63	0.78	1.59	0.62	0.62	0.40	-	0

Table A4.6
Evaluation of Two-Quarter Forecasts of Current Dollar GDP Growth (1980Q2-1988Q2)

	Average growth rate: Historical	Average growth rate: Predicted	r	ME	MAE	RMSE	Maximum error	PM
BMY	4.31	4.96	0.63	-0.65	1.21	1.57	3.93	0.66
MMY	4.31	4.54	0.61	-0.24	1.13	1.50	4.45	0.70
M1Y	4.31	4.69	0.70	-0.38	1.06	1.76	3.02	0.52
M2Y	4.31	4.81	0.66	-0.50	1.21	1.64	2.53	0.78
M3Y	4.31	4.72	0.70	-0.42	1.07	1.46	2.53	0.62
M4Y	4.31	4.77	0.67	-0.47	1.15	1.42	3.02	0.58
C1Y	4.31	4.97	0.40	-0.66	1.56	2.04	4.23	1.20
C2Y	4.31	4.64	0.33	-0.34	1.46	1.95	3.78	1.19
C3Y	4.31	4.43	0.51	-0.13	1.25	1.55	4.10	0.76
C4Y	4.31	5.30	0.55	-0.99	1.46	1.88	2.49	0.82
C5Y	4.31	4.58	0.60	-0.27	1.21	1.49	3.15	0.69
C6Y	4.31	5.15	0.47	-0.84	1.45	1.82	3.41	0.84
MI1Y	4.31	4.62	0.77	-0.31	0.84	1.19	2.82	0.42
MI2Y	4.31	4.77	0.80	-0.46	0.89	1.17	2.08	0.37
MI3Y	4.31	4.70	0.78	-0.40	0.92	1.19	2.97	0.40
MI4Y	4.31	4.85	0.77	-0.54	1.04	1.28	2.04	0.43
MI5Y	4.31	4.50	0.43	-0.19	1.46	1.76	4.29	0.98
MI6Y	4.31	4.54	0.49	-0.23	1.48	1.91	3.81	1.16
MI7Y	4.31	5.22	0.46	-0.91	1.56	1.89	3.47	0.89
MI8Y	4.31	5.25	0.51	-0.94	1.60	2.03	2.99	1.03
COM1Y	4.31	4.81	0.71	-0.50	1.07	1.38	3.04	0.53
COM2Y	4.31	4.71	0.70	-0.39	1.05	1.34	2.85	0.52

Table A4.7
Evaluation of Current-Quarter Forecasts of Current Dollar GDP Growth:
Indicator Models With Contemporaneous Financial Aggregates (1980Q2-1989Q2)

	Average growth rate: Historical	Predicted	r	ME	MAE	RMSE	Maximum error	PM	N	NG	NPT	NFS
BBMY	2.12	2.05	0.67	-0.07	0.57	0.76	1.71	0.61	0.65	0.20	-	0
BMMY	2.12	2.09	0.69	0.03	0.58	0.76	1.53	0.63	0.62	0.20	-	0
BM1Y	2.12	2.06	0.59	0.06	0.56	0.78	2.06	0.67	0.62	0.20	-	0
BM2Y	2.12	2.07	0.59	0.04	0.71	0.90	1.51	0.88	0.70	0	-	2
BM3Y	2.12	2.10	0.62	0.02	0.59	0.78	1.74	0.67	0.65	0	-	0
BM4Y	2.12	2.03	0.57	0.08	0.65	0.85	1.83	0.78	0.68	0.20	-	0
BC1Y	2.12	2.27	0.34	-0.16	0.76	0.96	2.45	0.98	0.46	0	-	0
BC2Y	2.12	2.26	0.41	-0.15	0.75	0.93	2.17	0.92	0.46	0	-	0
BC3Y	2.12	2.23	0.61	-0.11	0.56	0.77	2.02	0.63	0.62	0.20	-	0
BC4Y	2.12	2.22	0.60	-0.10	0.62	0.85	2.41	0.78	0.51	0.20	-	0
BC5Y	2.12	2.27	0.57	-0.16	0.61	0.82	2.36	0.70	0.62	0.20	-	0
BC6Y	2.12	2.17	0.63	-0.06	0.59	0.79	2.27	0.68	0.43	0.20	-	0
BMI1Y	2.12	2.24	0.68	-0.12	0.57	0.71	1.55	0.54	0.59	0.20	-	0
BMI2Y	2.12	2.28	0.73	-0.17	0.55	0.68	1.41	0.48	0.65	0	-	0
BMI3Y	2.12	2.21	0.69	-0.09	0.56	0.71	1.33	0.54	0.65	0.20	-	0
BMI4Y	2.12	2.26	0.71	-0.14	0.55	0.69	1.32	0.51	0.65	0	-	0
BMI5Y	2.12	2.05	0.51	0.07	0.66	0.86	2.69	0.80	0.62	0.20	-	0
BMI6Y	2.12	2.09	0.54	0.03	0.70	0.88	2.59	0.84	0.62	0.20	-	2
BMI7Y	2.12	1.99	0.57	0.12	0.61	0.86	2.71	0.79	0.51	0	-	0
BMI8Y	2.12	2.03	0.60	0.08	0.65	0.90	2.56	0.86	0.49	0.20	-	4
BCOM1Y	2.12	2.08	0.66	0.04	0.56	0.74	1.65	0.59	0.68	0	-	0
BCOM2Y	2.12	2.07	0.61	0.04	0.57	0.78	1.94	0.65	0.62	0.20	-	0

Table A4.8
Evaluation of the Current-Quarter Forecasts of the Growth of Real GDP, the GDP Deflator, the Consumer Price Index, and Private Demand Components (1980Q2-1989Q2)

	Real GDP				GDP deflator				Fixed-weight deflator	CPI
Model:	MBQ	MMQ	C1Q	C2Q	MBP	MMP	CIP	C2P		
Forecast										
Average historical growth rate	0.79	0.79	0.79	0.79	1.32	1.32	1.32	1.32	1.39	1.59
Average projected growth rate	0.82	0.85	0.71	1.06	1.46	1.47	1.43	1.43	1.55	1.55
Correlation of historical & projected growth rate	0.68	0.64	0.43	0.52	0.86	0.75	0.83	0.65	0.83	0.88
Forecast error										
ME	-0.03	-0.06	0.08	-0.27	-0.14	-0.15	-0.12	-0.18	-0.16	-0.01
MAE	0.61	0.68	0.79	0.76	0.35	0.46	0.35	0.49	0.30	0.30
RMSE	0.74	0.78	0.94	0.94	0.42	0.57	0.44	0.63	0.41	0.38
Maximum error	1.64	1.65	2.04	1.74	0.55	1.13	0.77	1.01	0.61	0.38
PM	0.53	0.60	0.87	0.81	0.26	0.52	0.32	0.62	0.33	0.23
UM	0	0.01	0.01	0.08	0.12	0.07	0.07	0.08	0.15	0
UR	0	0.01	0.07	0.09	0	0.15	0.01	0.06	0.03	0.03
UD	0.99	0.98	0.92	0.83	0.88	0.78	0.92	0.86	0.97	0.77
α	-0.06 (0.29)	0.06 (0.32)	0.34 (1.58)	0.13 (0.52)	-0.16 (0.99)	0.12 (0.59)	-0.18 (0.97)	0.21 (0.86)	-0.05 (0.29)	-0.21 (1.22)

(cont'd)

Table A4.8 (cont'd)
Evaluation of the Current-Quarter Forecasts of the Growth of Real GDP, the GDP Deflator, the Consumer Price Index, and Private Demand Components (1980Q2-1989Q2)

	Real GDP				GDP deflator				Fixed-weight deflator	CPI
Model:	MBQ	MMQ	C1Q	C2Q	MBP	MMP	C1P	C2P		
β	1.05	0.88	0.68	0.65	1.02	0.83	1.04	0.73	0.94	1.13
	(5.38)	(4.93)	(3.05)	(3.60)	(3.27)	(6.51)	(8.36)	(4.87)	(8.54)	(10.65)
δ	0.18	0.25	0.23	0.35	0.09	0.09	0.14	0.22	-0.01	0.14
	(1.09)	(1.50)	(1.41)	(2.18)	(0.51)	(0.55)	(0.83)	(1.32)	(0.04)	(0.84)
Q2	1.25	0.68	0.79	3.06	2.53	3.46	1.93	4.19	0.70	1.20
Q4	3.23	3.25	5.51	3.36	8.81	10.19	9.54	7.12	1.12	1.40
Q6	3.91	3.58	6.78	7.66	14.49	13.61	13.33	9.59	3.50	4.47
Q8	6.24	3.85	12.16	19.61	18.98	19.51	15.75	10.36	5.00	7.48
Inv.$	!	!	!	!	!	!	!	!	!	!
Trade balance	!	!	!	!	!	!	!	!	!	!
Oil	!	!	!	!	!	!	!	=	!	!
Forecast of the sign of the change in the growth rate										
N	0.59	0.59	0.38	0.49	0.49	0.46	0.27	0.35	0.41	0.41
NG	0	0	0.20	0	0	0	0	0	0	0
NTP	2	1	2	0	-	-	-	-	-	-
NFS	2	1	2	2	0	0	0	0	0	0

(cont'd)

Table A4.8 (cont'd)
Evaluation of the Current-Quarter Forecasts of the Growth of Real GDP, the GDP Deflator, the Consumer Price Index, and Private Demand Components (1980Q2-1989Q2)

	Consumption				Housing			
Model:	**MC$**	**MPC**	**MC**	**P*C**	**MH$**	**MPH**	**MH**	**PH*H**
Forecast								
Average historical growth rate	2.23	1.45	0.82	2.29	2.88	1.51	1.33	2.88
Average projected growth rate	2.44	1.46	0.74	2.20	1.77	0.58	0.83	2.40
Correlation of historical & projected growth rate	0.18	0.86	0.45	0.10	0.48	0.20	0.45	0.43
Forecast error								
ME	-0.16	-0.01	0.09	0.09	1.10	0.06	0.50	0.47
MAE	0.63	0.33	0.69	0.73	3.99	0.96	3.65	4.00
RMSE	0.87	0.39	0.88	0.98	4.93	1.28	4.46	4.99
Maximum error	1.41	0.33	2.53	2.64	13.40	4.04	6.32	11.26
PM	1.19	0.26	1.04	1.57	0.80	1.41	0.83	0.85
UM	0.03	0	0.01	0.01	0.05	0	0.01	0.01
UR	0.19	0.01	0.24	0.38	0.03	0.33	0.04	0.05
UD	0.99	0.75	0.62	0.92	0.67	0.95	0.95	0.95
α	1.57 (2.38)	-0.11 (0.61)	0.50 (2.76)	2.04 (4.44)	1.85 (2.15)	1.13+ (1.18)	1.03 (1.45)	1.50 (1.55)
β	0.30 (1.11)	1.07 (3.42)	0.45 (2.76)	0.11 (0.56)	0.74 (3.38)	0.23+ (1.19)	0.72 (3.23)	0.69 (2.97)

(cont'd)

Table A4.8 (cont'd)
Evaluation of the Current-Quarter Forecasts of the Growth of Real GDP, the GDP Deflator, the Consumer Price Index, and Private Demand Components (1980Q2-1989Q2)

	Consumption				Housing			
Model:	MC$	MPC	MC	P*C	MH$	MPH	MH	PH*H
δ	0.02 (0.10)	0.07 (0.41)	0.17 (0.01)	0.23 (1.40)	0.06 (0.37)	0.02 (0.14)	-0.05 (0.28)	-0.06 (0.33)
Q2	0.21	3.69	1.31	3.68	0.29	1.23	0.63	0.08
Q4	1.69	4.19	5.05	4.61	2.90	8.37	2.90	2.97
Q6	7.43	10.12	8.94	14.19	3.28	9.30	4.06	3.10
Q8	8.51	12.70	13.49	17.78	4.69	9.61	6.47	5.75
Inv.$	!	!	=	!	!	**	!	!
Trade balance	!	!	=	!	!	*	!	!
Oil	!	!	!	!	!	!	!	!
Forecast of the sign of the change in the growth rate								
N	0.43	0.43	0.54	0.46	0.57	0.43	0.51	0.54
NG	0	0	0	0	0.15	0	0.31	0.33
NTP	-	-	2	-	4	0	8	4
NFS	0	0	4	0	11	2	7	6

(cont'd)

Table A4.8 (cont'd)
Evaluation of the Current-Quarter Forecasts of the Growth of Real GDP, the GDP Deflator, the Consumer Price Index, and Private Demand Components (1980Q2-1989Q2)

	Investment				Private domestic demand			
Model:	MI$	MPI	MI	PI*I	MDD$	C$+HI+I$	DD	PDD
Forecast								
Average historical growth rate	1.76	0.33	1.41	1.76	2.22	2.22	0.96	1.25
Average projected growth rate	2.18	0.42	1.46	1.88	2.39	2.17	0.88	1.29
Correlation of historical & projected growth rate	0.47	0.59	0.55	0.57	0.53	0.43	0.57	0.88
Forecast error								
ME	-0.42	-0.07	-0.05	-0.13	-0.17	0.05	0.08	-0.04
MAE	2.28	0.66	2.33	2.11	0.68	0.77	0.76	0.28
RMSE	2.87	0.86	2.77	2.62	0.97	1.06	1.04	0.34
Maximum error	3.12	1.82	4.83	4.52	2.13	3.27	2.96	0.71
PM	0.79	0.69	0.68	0.67	0.72	0.88	0.68	0.23
UM	0.02	0.01	0	0	0.03	0	0.01	0.01
UR	0.01	0.04	0.01	0	0.03	0.08	0.01	0.02
UD	0.97	0.95	0.99	1.00	0.94	0.92	0.98	0.97
α	-0.11 (0.15)	0.03 (0.16)	-0.23 (0.35)	-0.17 (0.26)	0.09+ (0.18)	0.87+ (1.73)	0.26+ (0.98)	-0.16 (1.07)
β	0.89 (3.29)	0.76 (4.21)	1.15 (3.92)	1.04 (1.14)	0.92+ (1.67)	0.63+ (2.17)	0.84+ (3.31)	1.09 (10.36)

(cont'd)

Table A4.8 (cont'd)
Evaluation of the Current-Quarter Forecasts of the Growth of Real GDP, the GDP Deflator, the Consumer Price Index, and Private Demand Components (1980Q2-1989Q2)

	Investment				Private domestic demand			
Model:	**MI$**	**MPI**	**MI**	**PI*I**	**MDD$**	**C$+HI+I$**	**DD**	**PDD**
δ	0.12 (0.69)	-0.41 (2.54)	0.24 (1.55)	0.29 (0.77)	0.23 (1.53)	0.35 (2.21)	0.36 (2.29)	0.29 (1.77)
Q2	1.06	6.65	2.31	3.35	3.82	0.49	3.83	2.68
Q4	2.30	7.32	2.95	3.77	6.55	1.41	4.65	4.89
Q6	6.03	9.13	6.61	8.66	2.59	1.77	5.48	7.35
Q8	6.82	9.73	6.94	8.74	15.65	5.70	6.27	11.19
Inv.$	**	!	=	*	**	**	!	!
Trade balance	**	!	**	**	*	*	=	!
Oil	**	!	*	**	!	=	!	!
Forecast of the sign of the change in the growth rate								
N	0.46	0.30	0.51	0.18	0.57	0.54	0.43	0.46
NG	0.06	0	0.22	0	0	0	0	0
NTP	1	4	8	1	0	0	1	·
NFS	5	4	7	5	0	0	3	0

Table A4.9
Evaluation of One-Quarter-Ahead Forecasts of Growth of Constant Dollar GDP, GDP Deflator, Consumer Price Index, and Private Demand Components (1980Q2-1989Q2)

	Average growth rate: H*	P**	ſ	ME	MAE	RMSE	Maximum error	PM	N	NG	NPT	NFS
GDP, constant dollars												
MBQ	0.79	0.82	0.67	-0.03	0.62	0.74	1.60	0.55	0.59	0	2	2
MMQ	0.79	0.86	0.66	-0.07	0.67	0.76	1.39	0.56	0.59	0	1	2
C1Q	0.79	0.74	0.26	0.05	0.87	1.02	1.95	1.03	0.41	0	1	7
C2Q	0.79	1.11	0.52	-0.32	0.79	0.97	1.50	0.82	0.51	0	1	3
GDP deflator												
MBP	1.32	1.50	0.83	-0.19	0.37	0.46	0.52	0.31	0.51	0	-	0
MMP	1.32	1.51	0.69	-0.19	0.52	0.66	1.25	0.69	0.49	0	-	0
C1P	1.32	1.48	0.78	-0.16	0.39	0.50	0.94	0.40	0.46	0	-	0
C2P	1.32	1.56	0.54	-0.25	0.53	0.72	1.04	0.79	0.46	0	-	0
FWP	1.39	1.60	0.81	-0.21	0.35	0.45	0.59	0.36	0.51	0	-	0
CPI												
MCPI	1.54	1.57	0.85	-0.03	0.34	0.42	1.01	0.28	0.49	0	-	0
Consumption												
MC$	2.29	2.51	0.18	-0.22	0.69	0.93	1.36	1.33	0.43	0	-	0
MPC	1.45	1.46	0.82	0	0.37	0.44	1.00	0.33	0.43	0	-	0
MC	0.82	0.80	0.48	0.02	0.66	0.84	2.48	0.97	0.38	0	1	7
PC*C	2.29	2.26	0.23	0.03	0.73	0.95	2.55	1.48	0.51	0	-	0

H* = Historical
P** = Predicted

(cont'd)

Table A4.9 (cont'd)
Evaluation of One-Quarter-Ahead Forecasts of Growth of Constant Dollar GDP, GDP Deflator, Consumer Price Index, and Private Demand Components (1980Q2-1989Q2)

	Average growth rate:						Maximum					
	H*	P**	∫	ME	MAE	RMSE	error	PM	N	NG	NPT	NFS
Housing												
MH$	2.88	1.33	0.40	1.55	4.41	5.17	9.00	0.84	0.65	0.08	1	9
MPH	1.51	1.55	0.06	-0.04	1.07	1.38	4.31	1.65	0.49	0	0	4
MH	1.33	0.65	0.26	0.68	4.07	4.86	7.91	0.97	0.62	0.23	7	9
PH*H	2.88	2.20	0.27	0.68	4.56	5.32	8.10	0.96	0.59	0.23	2	8
Investment												
MI$	1.76	2.43	0.29	-0.67	2.41	3.19	5.68	0.95	0.51	0	1	3
MPI	0.35	0.53	0.58	-0.18	0.68	0.88	1.76	0.68	0.68	0.20	3	5
MI	1.41	1.52	0.38	-0.11	2.46	3.07	4.73	0.86	0.62	0.30	7	9
PI*I	1.76	2.05	0.39	-0.29	2.36	2.37	4.68	0.85	0.62	0	0	2
Private domestic demand												
MDD$	2.22	2.44	0.48	-0.21	0.72	1.03	2.00	0.80	0.62	0	0	0
C$+H$+I$	2.22	2.23	0.53	-0.01	0.71	0.96	2.81	0.73	0.59	0	0	0
DD	0.97	0.93	0.61	-0.04	0.73	1.00	2.50	0.64	0.59	0	1	1
PDD	1.29	1.30	0.80	-0.06	0.36	0.43	0.70	0.36	0.41	0	-	0

H* = Historical
P** = Predicted

Table A4.10
Evaluation of Two-Quarter Forecasts of Growth of Constant Dollar GDP, GDP Deflator, Consumer Price Index, and Private Demand Components (1980Q2-1989Q2)

	Average growth rate: H*	P**	r	ME	MAE	RMSE	Maximum error	PM
GDP, constant dollars								
MBQ	1.59	1.64	0.76	-0.05	0.99	1.17	2.42	0.43
MMQ	1.59	1.73	0.73	-0.13	1.06	1.23	2.52	0.47
C1Q	1.59	1.46	0.43	0.14	1.39	1.65	3.66	0.85
C2Q	1.59	2.16	0.58	-0.57	1.33	1.65	2.95	0.76
GDP deflator								
MBP	2.68	3.02	0.89	-0.34	0.58	0.76	0.69	0.21
MMP	2.68	3.06	0.78	-0.37	0.88	1.13	1.91	0.51
C1P	2.68	2.96	0.85	-0.27	0.64	0.84	1.38	0.28
C2P	2.68	3.10	0.68	-0.42	0.92	1.19	1.69	0.55
FWP	2.85	3.22	0.88	-0.36	0.58	0.73	0.88	0.23
CPI								
MCPI	3.13	3.18	0.90	-0.05	0.60	0.71	1.50	0.20
Consumption								
MC$	4.63	5.03	0.31	-0.40	0.97	1.44	2.06	1.17
MPC	2.96	2.98	0.89	-0.02	0.59	0.71	1.59	0.22
MC	1.64	1.52	0.69	0.12	0.88	1.10	2.64	0.62
PC*C	4.63	4.52	0.36	0.11	1.06	1.40	3.10	1.19

H* = Historical
P** = Predicted

(cont'd)

Table A4.10 (cont'd)
Evaluation of Two-Quarter Forecasts of Growth of Constant Dollar GDP, GDP Deflator, Consumer Price Index, and Private Demand Components (1980Q2-1989Q2)

	Average growth rate:							
	H*	P**	∫	ME	MAE	RMSE	Maximum error	PM
Housing								
MH$	6.02	3.04	0.44	2.98	6.65	8.64	21.03	0.81
MPH	3.12	3.14	0.27	-0.01	1.73	2.15	5.24	1.30
MH	2.77	1.40	0.33	1.37	6.62	7.91	13.21	0.32
PH*H	6.02	4.57	0.36	1.44	7.12	8.65	17.59	0.90
Investment								
MI$	3.59	4.78	0.46	-1.18	3.92	27.54	11.06	0.80
MPI	0.67	1.01	0.64	-0.35	1.16	1.49	2.21	0.64
MI	2.94	3.02	0.50	-0.08	3.99	5.13	9.04	0.76
PI*I	3.59	4.04	0.50	-0.44	3.69	4.98	8.07	0.75
Private domestic demand								
MDD$	4.52	4.91	0.59	-0.39	1.18	1.71	3.65	0.67
C$+H$+I$	4.52	4.46	0.57	0.06	1.23	1.67	4.35	0.68
DD	1.95	1.80	0.70	0.15	1.22	1.68	3.31	0.54
PDD	2.54	2.64	0.87	-0.11	0.60	0.71	1.31	0.25

H* = Historical
P** = Predicted

Table A4.11
Evaluation of Current-Quarter Forecasts of Constant Dollar GDP Growth, GDP Deflator, Consumer Price Index, and Private Demand Components: Models with Contemporaneous Financial Aggregates (1980Q2-1989Q2)

	Average growth rate:											
	H*	P**	∫	ME	MAE	RMSE	Maximum error	PM	N	NG	NPT	NFS
GDP, constant dollars												
BMBQ	0.79	0.78	0.67	0	0.62	0.75	1.68	0.55	0.59	0	2	2
BMMQ	0.79	0.76	0.65	0.03	0.65	0.77	1.88	0.58	0.57	0	2	2
BC1Q	0.79	0.78	0.56	0.01	0.66	0.84	2.23	0.70	0.62	0.20	1	5
BC2Q	0.79	0.72	0.57	0.07	0.60	0.85	2.30	0.71	0.57	0	0	2
GDP deflator												
BMBP	1.32	1.27	0.80	0.05	0.41	0.47	0.85	0.38	0.70	0	-	0
BMMP	1.32	1.31	0.70	0.01	0.46	0.56	1.34	0.53	0.65	0	-	0
BC1P	1.32	1.45	0.83	-0.13	0.37	0.45	0.90	0.32	0.46	0	-	0
BC2P	1.32	1.50	0.83	-0.18	0.38	0.46	0.66	0.31	0.32	0	-	0
Consumption												
BMC$	2.20	2.31	0.33	-0.03	0.66	0.77	1.67	0.98	0.49	0	-	0
BMPC	1.45	1.45	0.84	0	0.34	0.41	0.93	0.29	0.51	0	-	0
BMC	0.82	0.88	0.55	-0.06	0.55	0.76	2.46	0.79	0.51	0	0	3
PC*C	2.29	2.34	0.24	-0.05	0.66	0.84	2.59	1.13				

H* = Historical
P** = Predicted

(cont'd)

Table A4.11 (cont'd)
Evaluation of Current-Quarter Forecasts of Constant Dollar GDP Growth, GDP Deflator, Consumer Price Index, and Private Demand Components: Models with Contemporaneous Financial Aggregates (1980Q2-1989Q2)

	Average growth rate:											
	H*	P**	ſ	ME	MAE	RMSE	Maximum error	PM	N	NG	NPT	NFS
Housing												
BMH$	2.88	1.28	0.57	1.60	3.92	4.87	12.15	0.74	0.59	0.23	4	13
BMPH	1.51	1.22	0.13	0.29	2.80	3.98	10.45	1.36	0.51	0	3	11
BMH	1.33	0.19	0.53	1.14	3.45	4.42	11.03	0.77	0.46	0.23	3	7
PH*H	2.88	1.41	0.41	1.47	4.78	6.57	19.53					
Investment												
BMI$	1.76	2.12	0.46	-0.36	2.34	2.88	5.20	0.80	0.43	0	1	9
BMPI	0.35	0.71	0.56	-0.35	0.78	0.98	1.88	0.77	0.46	0.30	3	5
BMI	1.41	-0.01	-0.04	1.50	4.48	7.44	34.03	4.84	0.59	0.28	7	9
BPI*I	1.76	0.61	-0.03	1.14	4.45	7.42	32.85	5.23				
Private domestic demand												
BMDD$	2.22	1.97	0.40	0.25	1.04	1.33	3.35	1.34	0.57	0.33	1	5

H* = Historical
P** = Predicted

Appendix 5

Table A5.1
Comparison of Estimation Results of MBQ and CIP Models with Seasonally Adjusted and Non-Seasonally Adjusted Data (1972Q1-1989Q2)

	MBQ Model Goal variable: Q				C1P Model Goal variable: P		
	(1)	(2)	(3)		(1)	(2)	(3)
Constant	0.839	1.375	-8.095	**Constant**	0.115	1.835	1.282
	(6.01)	(2.29)	(14.70)		(0.63)	(3.72)	(1.97)
Q_{-1}	0.052	-0.090	-0.613	**P_{-1}**	0.396	-0.192	-0.128
	(0.46)	(0.65)	(6.38)		(3.50)	(1.56)	(1.04)
$M1R_{-1}$	0.168	-0.315	0.202	**P_{-2}**	0.393	-0.257	-0.149
	(3.49)	(1.30)	(2.27)		(3.60)	(2.13)	(1.24)
$M1R_{-2}$	0.168	-0.929	0.343	**CCB_{-1}**	0.078	0.213	0.272
	(3.19)	(4.63)	(3.85)		(1.98)	(1.73)	(2.23)
Q2	-	-	10.24	**Q2**	-	-	0.707
			(15.61)				(0.96)
Q3	-	-	19.85	**Q3**	-	-	1.044
			(17.28)				(1.47)
Q4	-	-	8.91	**Q4**	-	-	-1.522
			(7.50)				(2.08)
$\bar{R}^2$	0.337	0.277	0.926	**$\bar{R}^2$**	0.617	0.056	0.214
D.W.	2.02	1.75	2.06	**D.W.**	2.01	1.99	1.94
S.E.E.	0.785	4.888	1.564	**S.E.E.**	0.580	2.099	1.916
$\Sigma M1R$	0.334	-1.244	0.546				
	(5.18)	(4.68)	(4.63)				

(1) = estimation with seasonally adjusted data.
(2) = estimation with non-seasonally adjusted data.
(3) = estimation with non-seasonally adjusted data and seasonal dummy variables.

Table A5.2
Nonlinear Relationship Between Real M1 Growth and Growth of Constant Dollar GDP (1972Q2-1989Q2)

	(1)	(2)	(3)
Constant	0.839 (6.01)	0.978 (4.36)	0.906 (4.96)
Q_{-1}	0.052 (0.46)	0.033 (0.29)	0.045 (0.39)
$M1R_{-1}$	0.168 (3.49)	0.090 (0.93)	0.162 (3.27)
$M1R_{-2}$	0.166 (3.19)	0.172 (1.76)	0.169 (3.12)
$M1R_{-1} < O$	-	0.144 (0.92)	-
$M1R_{-2} < O$	-	0.006 (0.04)	-
$M1R^2_{-1}$	-	-	-0.008 (0.45)
$M1R^2_{-2}$	-	-	-0.006 (0.35)
$\bar{R}^2$	0.337	0.325	0.320
D.W.	2.02	2.01	2.04
S.E.E.	0.784	0.791	0.795
ΣM1	0.334 (5.18)	0.412 (3.57)	0.315 (4.30)
F - test for additional variables	-	0.273	0.102

(1) = estimation with seasonally adjusted data.
(2) = estimation with non-seasonally adjusted data.
(3) = estimation with non-seasonally adjusted data and seasonal dummy variables.

Table A5.3
Indicator Model and Statistics Canada's Leading Indicator
Goal Variable: Constant Dollar GDP (1972Q2-1989Q2)

	(1)	(2)	(3)
Constant	0.839 (6.01)	0.847 (5.83)	0.813 (5.59)
Q_{-1}	0.052 (0.46)	0.061 (0.51)	0.027 (0.23)
$M1R_{-1}$	0.168 (3.49)	0.170 (3.43)	0.183 (3.67)
$M1R_{-2}$	0.166 (3.19)	0.173 (2.83)	0.164 (2.68)
$LIND_{-2}$	-	-0.016 (0.23)	-0.045 (0.63)
$LIND_{-3}$	-	-	0.085 (1.54)
$\bar{R}^2$	0.34	0.33	0.34
D.W.	2.02	2.02	1.93
S.E.E.	0.78	0.79	0.78
ΣM1R	0.334 (5.18)	0.344 (4.40)	0.346 (4.48)
ΣLIND	-	-	0.040 (0.51)

(1) = estimation with seasonally adjusted data.
(2) = estimation with non-seasonally adjusted data.
(3) = estimation with non-seasonally adjusted data and seasonal dummy variables.

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Commentary

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by John McCallum

I would like to congratulate Patrice Muller for a most exhaustive study of this subject. I have learned a lot from this paper. An incredible amount of work has gone into this project - enormous numbers of regressions and enormous numbers of numbers for a discussant like me to refer to. I would like to divide my comments into three parts. First, I would like to discuss briefly the objective of the paper and its conclusions. Second, I would like to talk about what I would call the transmission mechanism. And, third, I want to say something about the comparisons that Patrice makes between predictions based on aggregates and the private-sector forecasts of DRI and the Conference Board.

First, in terms of purpose. It is a limited purpose: to see whether the monetary or credit aggregates provide useful information in making short-term forecasts about nominal GDP, prices and output. It has nothing in particular to do with monetary policy - just an attempt to discover whether the aggregates help us to make a short-term forecast. And the conclusion is, and I quote, "Despite the many financial innovations that have affected the relationship between financial aggregates and total spending, these aggregates remain extremely useful sources of information on developments in the major macroeconomic aggregates."

My first comment is a relatively minor one. If the only objective is to use reduced forms to help predict nominal GDP and so on, it does not seem necessary to limit the variables to financial variables. This may lead to hundreds more regressions if it's tried - and maybe it already has been - but one can think of other things that might be useful. For instance, if one wishes to predict the GDP deflator, perhaps lagged values of the exchange rate or commodity prices would be useful. If one wishes to predict real output, then maybe lagged values of U.S. output or other U.S. variables could improve the predictions.

Second, I would like to move on to a more substantive point regarding the "transmission mechanism" mentioned earlier. Now, perhaps one cannot talk too much about the transmission mechanism with such reduced-form equations, but at least one would have to have some kind of intelligible story for why certain results are obtained.

At the risk of considerable simplification, given the large number of results, I would like to offer this brief summary of those results. There are the fitted equations and then there are tests to see which models work best in out-of-sample forecasts. For real GDP (Q), real M1 works best - both in the fitted equations and in the forecasts. To predict the GDP deflator, it seems that the best aggregate is either M2 or consumer credit offered by banks. To predict nominal GDP in the fitted equations, the best aggregate seems to be M1, but for the forecasts, the author takes the sum of the output forecasts and the price forecasts based on consumer credit to arrive at nominal GDP forecasts. I believe that Milton Friedman would argue that if money increases, then we should see an effect on nominal GDP within, say, a year, and we should see an effect in terms of prices somewhat later. I am not quite sure what is behind these results, but I would like to raise one or two questions.

First, it seems odd to me that you have different monetary aggregates forecasting output versus prices versus nominal GDP. Real M1 seems best for output, pretty good for nominal GDP, but not much use for prices. M2 seems reasonably good for prices, but not much good for the other two. So, what kind of story could lie behind this situation? Why would one expect to see this? The findings on M1 also puzzle me a little because there has been much literature on how the demand for M1 has broken down, but here we see M1 making a bit of a comeback as it is the best aggregate for predicting output. So, essentially, shifts in the LM curve, due to shifts in M1, are useful predictors of output. However, at the same time, another branch of the literature says that there are major shifts in the LM curve because of shifts in the demand for M1. So is it not a little puzzling that of all these aggregates, M1 seems to be the best for predicting output? Also, M1 seems to work best overall, if one looks at output, prices and nominal income combined, because when I examined the correlation coefficients at different lags and leads between various monetary aggregates and the other variables of interest, I found that one gets a Friedman-type story if M1 is used.

For instance, I noticed that if M1 goes up at t=0, at t=2 you get the maximum correlation for output and nominal GNP. The correlation coefficient is 0.78. And then at t=4 (t measured in quarters) you get the maximum correlation with prices, although that correlation is low. So if M1 is used, one gets M1 going up today, two quarters later output and nominal GDP respond, and four quarters later the maximum price response is felt. This is puzzling because M1 has had all these other problems relating to stability.

So let us look at M2. M2 seems to be the best for predicting prices, but not so good for explaining the other two variables. If M2 goes up at t=0, then approximately at the same time, the price level goes up, but the increases in nominal GDP and output precede the increase in M2. Thus, one has a preceding t=-2 increase in nominal income with a high correlation coefficient and four quarters prior, an increase in output with a correlation of 0.62. I cannot tell any intelligible story or call it a transmission mechanism explanation, as to why there is this pattern of leads and lags with prices, nominal income and real GDP. This detracts from my confidence in focussing only on M2's relatively good performance in helping to predict prices. I guess I am a little sceptical because there does not seem to be any unifying or intelligible story as to what is going on behind these regressions.

Now let me come to my third and final point, which is the comparison with the private forecasts. In a sense, this is the bottom line or the critical issue because, if the object of this work is to see whether the monetary aggregates are an aid to forecasting, we would like to see whether they are superior relative to other available forecasts. Hence, the author compares the forecasts produced by the monetary aggregate models with DRI and Conference Board forecasts. To do this, he regresses the actual change in the variable of interest on both the Conference Board forecast and the forecast of the monetary-aggregate model, for example. In virtually every case, the forecasts of the monetary-aggregate model do not improve upon the private-sector forecasts for either nominal GDP or real GDP, except in one case involving real GDP and the Conference Board.

However, where the monetary aggregate forecasts do appear to improve materially over the private-sector forecasts is with regard to GDP deflator growth, if one takes the Conference Board forecast. In Table 23, the indicator model based on M2 improves substantially over the Conference Board forecast, suggesting that taking account of M2 growth improves very significantly the short-term forecast of inflation relative to Conference Board forecasts. Clearly this is an important and useful piece of information. However, I should note the following: (i) this pattern of M2 is disconcerting to me and detracts from the reliability of the conclusion; (ii) the inclusion of M2 does not seem to improve upon DRI forecasts; and (iii) there are some suggestions through the paper that this M2 relationship, which passes certain stability tests, may have broken down around 1985. I would be interested to see the result if this inflation prediction equation based on M2 were estimated up to 1985. Would it perform well over the last five years, or has there been a breakdown in this relationship in recent years?

To summarize, this has been an interesting paper. It does suggest that M2 is useful in predicting inflation, but I am a little uneasy because of the likelihood of instability. Also, given the patterns of the correlations that I observe in the paper, I cannot make much sense out of what kind of story or transmission mechanism lies behind the role of M2.

General Discussion

Bruce Rayfuse noted that there has been considerable debate recently as to whether the transmission mechanism of monetary policy has changed. He asked whether there was any evidence from the indicator models to support this view - for example, any evidence of recent instability or deterioration in the forecast performance of indicator models for individual components of aggregate demand. Patrice Muller replied that formal tests suggested no evidence of recent instability in the aggregate indicator models. Furthermore, when those models were estimated up to 1979 and then used to forecast over the 1985-89 period, the root-mean-squared error (RMSE) over the forecast interval showed no deterioration compared to the within-sample performance of the equation. For the component models, there was considerably more evidence of instability; however, Muller suggested that this might simply be due to the fact that such models were "overfitted" (i.e., they contained a large number of explanatory variables) and hence, less reliable out of sample.

Pierre Fortin commented that the formal tests for stability used in the paper might have fairly low power because the explanatory power of the indicator models was relatively weak. Muller replied that he placed less weight on the formal stability tests than on the fact that the *ex post* forecasting performance of his models did not deteriorate relative to the within-sample fit.

Jean-Marie Dufour reminded the participants that a model that is misspecified (e.g., with omitted variables or incorrect restrictions) may have a lower forecast RMSE than a correctly specified model when the parameter estimates of the correctly specified model have a larger variance. Pierre Fortin suggested that the weight one should give to evidence of such misspecification would depend on the purpose of the model: when the primary purpose is forecasting, a misspecified model with a lower RMSE might be preferred.

Paul Boothe wondered whether the stability of the aggregate indicator models suggested that the Lucas critique was not operative for the kinds of changes in monetary policy that had occurred over the sample period. Pierre Duguay agreed with Boothe that there had likely been changes in the economic structural relationships over the sample period, but felt that the aggregate indicator models remained stable enough to be useful as policy guides. In contrast, when one tried to increase the precision of the models by adding more explanatory variables or additional lags, they tended to be less stable and therefore less useful for monetary policy.

Freedman pointed out that indicator models are only one of many factors that are useful as policy guides. The Bank of Canada also does economic projections using the RDXF econometric model, looks at private-sector projections for the Canadian economy and monitors economic information as it becomes available. Indicator models play a role by confirming the signals provided by other available economic data. He noted that *both* money and credit provide useful information, though, on the whole, the information content of monetary aggregates seems to be somewhat greater. He added that the Bank does not focus on a single aggregate because at any given time, random shocks, special factors or financial innovation specific to a single aggregate could provide misleading signals. Muller commented that monetary and credit aggregates were especially useful because they are available on a much more timely basis than many other sources of economic data. This was one reason that he had restricted the scope of the indicator variables to money and credit aggregates in his models.

Doug Hostland added that only under very strong assumptions (including strong exogeneity of the monetary aggregates), which are unlikely to hold, can one give any structural interpretation to the properties of indicator models. If a structural interpretation is desired, one should use a VAR framework, make sufficient assumptions to identify the model, and then use innovation accounting to consider such structural interpretation.

Pierre Duguay agreed that there are problems in giving a structural interpretation to indicator models, but argued that the patterns of lead and lag relationships, as well as the fact that different monetary aggregates are better indicators for each of prices, output, and nominal income, are not inconsistent with the traditional view of the transmission mechanism. For example, the fact that M2 lags output but leads prices and that M1 leads output can be reconciled: because M1 is interest-sensitive and responds more quickly to interest rates than output, M1 will lead output. Later, the cumulative effects on output will influence prices, although with long and variable lags. These price and output changes also affect M2 demand gradually over time. But the correlation between M2 and prices peaks at shorter lags because both are responding to the preceding changes in output.

Jon Cockerline found it surprising that credit aggregates lagged real GDP movements since his impression from earlier Bank of Canada studies was that credit aggregates were leading indicators. Furthermore, a look at recent Canadian macroeconomic data seems to confirm that credit, especially residential mortgage credit, was leading the cycle. Muller pointed out that credit could still provide leading information, but that the correlation analysis suggested that the *maximum* correlation occurred when credit lagged output. He also noted that while some indicator models suggest that credit contains leading information, in many cases, this information is encompassed by that contained in M1. Bruce Montador pointed out that there is a problem with data availability when using credit as a leading indicator since "total household credit" is available only with a significant lag, although numbers for "chartered bank household credit" are available more quickly.

A BVAR MODEL FOR FORECASTING AND ANALYSIS OF CANADIAN MONETARY POLICY

by Daniel Racette and Jacques Raynauld*

Introduction

Two years ago, following a four-year period of approximately 4 per cent inflation, Bank of Canada Governor John Crow (1988) announced that the Bank would henceforth take all the actions necessary to achieve price stability. Since this announcement, many signals have shed some light on the difficulties in achieving this objective in the current financial and economic environment. Indeed, the inflation rate, as measured by the increase in the consumer price index, instead of decreasing, accelerated to 5.2 per cent for 1989 from 4.1 per cent in the first quarter of 1988. In addition, the variables regarded by the Governor as guides for monetary policy (M2 and M2+) have increased at well over a 10 per cent rate, much higher than the 5 to 6 per cent range compatible with price stability as indicated in recent Bank of Canada studies (Caramazza, 1989; see also Racette, 1989).[1]

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[1] Yet Governor Crow asserted recently: "However, the Bank of Canada is still ultimately capable of influencing the rate of monetary expansion in Canada." (*Bank of Canada Review*, April 1990, p. 37.)

* *We would like to thank David Longworth whose invitation to the Bank of Canada's Monetary Seminar initiated this research project. We would also like to thank Paul Boothe, Francesco Caramazza, Doug Hostland, Patrice Muller, and Jack Selody. While completing this project, Jacques Raynauld visited the Institute for Empirical Macroeconomics at the Federal Reserve Bank of Minneapolis where Christopher A. Sims and Richard Todd provided invaluable insights.*

Yet most observers of monetary policy (including the Governor himself, *Annual Report for 1989*, p. 9)[2] have continued to describe the current stance of Canadian monetary policy as very restrictive since the levels of short-term interest rates have risen to more than 12 per cent during 1989 and 1990 from less than 9 per cent at the beginning of 1988.

Canadian monetary policy is no longer conducted in a one-instrument (interest rate) one-intermediate-target (M1 rate of growth) environment. Financial innovations and deregulation have apparently made the demand for monetary aggregates unstable, and have also made the broader aggregates virtually insensitive to interest rates, rendering any monetary targeting operation perilous.[3] In this changing environment, nominal spending has become a key variable in the formulation of monetary policy. The Bank of Canada seems to adjust its policy after observing various variables presumed to be leading indicators of the movements of nominal spending (referred to as the "checklist" approach). In some sense this procedure is akin to nominal income targeting.[4] Developments over the last two years clearly illustrate the new and unforeseen difficulties that must now be faced by the Bank of Canada in the conduct of monetary policy.

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[2] Governor Crow is well aware that the Bank cannot determine the level of interest rates or of the exchange rate at will: "We cannot set the level of interest rates by fiat..." (Crow, 1990b, p. 36). Still, he identifies "monetary conditions" in the Canadian economy with the combined effects of interest rates and the exchange rate " ... of overall monetary conditions - that is, the combined effect on demand of a change in short-term interest rates and in the exchange rate." (Crow, 1990a, p. 11.)

[3] On this, see the following Bank of Canada studies: McPhail and Caramazza (1990), Caramazza, Hostland and Poloz (1990).

[4] "The contemporaneous and leading-indicator properties of M2+ and M2 with respect to nominal spending and inflation complement the information from the demand functions and from the analysis of other economic indicators in assessing current and prospective developments, and in guiding the authorities in adjusting the policy stance." (Caramazza et al., 1990, p. 421.)

"As I implied, there is a lot of judgment in deciding what setting of monetary conditions is necessary to achieve this outcome (reducing inflation) as economic conditions evolve. The Bank of Canada must take into account a range of factors affecting financial markets and our economy." (Crow, 1990b, p. 36)

This situation underlines the need for a flexible tool that the Bank can use to predict the key policy variables and to understand the dynamic interactions between the instruments, intermediate targets and ultimate policy objectives. In addition, such a tool should also permit an analysis of the leading-indicator properties of certain variables with respect to the various ultimate goals of the Bank.

Against this background, the Bank of Canada decided to initiate a research program to determine the properties of the demand for the broad monetary aggregates (M2, M2+) and to evaluate the forecasting performance of monetary and credit aggregates. The latter is very much geared for use in policy-making since researchers are being asked to:

- specify a model;
- justify its theoretical base;
- evaluate its forecasting performance over the 1980s and, if possible, compare the results to those obtained with traditional structural models;
- describe the technique used to forecast nominal spending for the most recent quarter;
- indicate the horizon over which it is possible to obtain useful economic forecasts;
- clarify (according to the model) the role played by the various financial aggregates in the determination of the level of spending and prices.

Economists at the Bank have examined a large set of monetary and credit aggregates to identify those with the best predictive ability with respect to the evolution of Canadian nominal spending (Hostland, Poloz and Storer, 1988; Milton, 1988; Freedman and Longworth, 1990; Crawford, 1989; Helwig and Muller, 1989; and Muller, 1989). To date, these studies have been based on cross-correlation analysis techniques to show the role financial aggregates play as indicators. The purpose of the exercise was to determine the best contemporaneous or long-term correlations between various money or credit aggregates and goal variables[5] such as nominal expenditure, real income and prices.[6] These studies were also supplemented by simple bivariate and multivariate methods.

While the thorough empirical search conducted at the Bank provided invaluable insights on the indicator properties of the monetary and credit aggregates, departure from the simple bivariate or multivariate framework is warranted. For example, a natural extension would be to examine the importance of additional macro variables along with the financial aggregates in the forecasting exercise and in the analysis of the contribution of the financial aggregates to the ultimate objectives of monetary policy.

Our decision to estimate a forecasting BVAR model of nominal spending in Canada should be interpreted in this broader perspective. As we will see, BVAR models are especially well suited to the problem at hand. For example, this type of methodology has been used successfully to forecast key U.S. macro variables (see Litterman, 1980, 1984, 1986; Doan, Litterman and Sims, 1984; Todd, 1984; McNees, 1986; Sims, 1989). Further, the BVAR model is a very flexible forecasting tool in that it can take into account the dynamic interrelations between a large set of variables without running into the over-parameterization problem often encountered in VAR applications. Finally, the BVAR methodology allows a more eclectic approach to modelling since it avoids the exclusions characteristic of the traditional estimation procedure. If we consider that the various macro theories do not have strong predictive abilities regarding the short-run links between the macro variables, together with the difficulty of explaining the complex problems facing monetary authorities using traditional theory, then we can see that a more flexible approach would be welcome. With the aid of generally accepted theory and statistical *a priori* information, BVAR models may lead to the detection of relationships that have been overlooked.[7]

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[5] As in the Bank of Canada studies, we will attach to this term the broad meaning of variables that are of interest to economic agents. (Muller, 1989, p. 3.)

[6] "For this study, a common yardstick is needed to provide a reasonable standard for comparison of the aggregates. In this context we consider a monetary aggregate economically relevant if it is highly correlated - correlation being defined in various ways - with total spending or nominal income in the economy." (Hostland, Poloz and Storer, 1988, p. 1.)

The objective here is to document the use of a BVAR model of the Canadian economy. In Section 1, we describe in more detail the problem faced by the monetary authorities, with special emphasis on the uncertain macroeconomic environment in which monetary policy is carried out in Canada. We also discuss the principal macro variables chosen to form our system and try to capture the degree of uncertainty inherent in them from a strictly statistical point of view. In Section 2, we justify our choice of the BVAR methodology. We also present a comprehensive guide to the specific aspects of this method. In Section 3, the estimation results and forecasting performance of the model in terms of the Canadian macroeconomic variables over the 1980s are discussed. Section 4 presents an analysis of the impact of various shocks on the chosen macroeconomic variables and tries to disentangle the effects of policy variables and foreign influences. Section 5 looks closely at the forecasting record of the model in 1988 and 1989. Finally, we conclude in Section 6 by indicating possible avenues for further research.

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[7] One can mention here the random-walk properties of macroeconomic variables and the long-term properties of well-known theoretical relationships between some of these variables.

1. The Canadian Macroeconomic Environment

1.1 The variables

The main goal here is to come up with the best possible forecast of Canadian nominal GDP. We also want to assess the contribution of various financial aggregates to the evolution of nominal spending and prices. Most observers will agree that this exercise must be conducted in a fairly global and open macroeconomic framework that includes a relatively large number of nominal variables. Since Canada is a small open economy, foreign influences (especially those from the United States) cannot be overlooked. The sample period (1970-1989) covers a single exchange rate regime, thus allowing us to avoid an important source of instability. We must emphasize that the openness of the Canadian economy greatly complicates the estimation of a model whose chief characteristic is its small and manageable scale.

The list of variables considered (see Table 1) comprises the following: two possible instruments of monetary policy (the monetary base and the interest rate); the narrowly defined monetary aggregate (M1) and the component leading to a broad definition of money (M2);[8] the exchange rate; and, finally, real income and prices - the two components of nominal spending which, as noted above, is a principal factor in the conduct of Canadian monetary policy.

The foreign variables include the U.S. variables that capture the most important real and financial channels of interdependence between the two countries, as well as two variables representing certain real shocks that marked the sample period.

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[8] "Also of interest was the finding that real GNE and the GNE deflator are predicted better by different monetary aggregates, with narrower aggregates performing best for the real component and broader aggregates for prices. This suggests that users of VAR models (VARs) might benefit from including two definitions of money, rather than the usual single definition." (Hostland et al., 1988, p. 44.)

Table 1
The Variables

Canadian variables

BASE = monetary base* (B2001 + B52 + B55 + B59)

M1 = narrow monetary aggregate (B1627)

M2-M1 = deposits in M2 excluding demand deposits = M2 - M1 (B1630-B1627)

TXCAN = short-term nominal interest rate - 90-day commercial paper rate (B14017)

TXCHA = Canadian dollar/U.S. dollar exchange rate, average noon spot rate (B3400)

GDPD = implicit price index of real gross domestic product, 1981=100 (D20337)

GDP = real gross domestic product (D20031)

Foreign variables

GNP82 = real U.S. gross national product (1982)

GNPD = U.S. GNP deflator

TXUS = short-term U.S. 90-day commercial paper rate (B54412)

RPCOM = international index of real commodities prices in U.S. dollars, excluding energy (series supplied by the Bank of Canada)

RPOIL = index of the real price of oil in U.S. dollars (series supplied by the Bank of Canada)

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* To take into account the Bank Act revision of 1980, we have imposed the same reserve requirements throughout the period and recalculated the BASE accordingly with a method proposed by Duguay (1983). The resulting BASE series was then adjusted for seasonal variations using the CENSUS method available in SAS. Figure 1 shows the two bases. For M1, M2, GDP, GDPD, GNP, and GNPD, we used the seasonally adjusted measures.

For comparison purposes, and to conform with the monetary policy process, we used seasonally adjusted quarterly time series.[9] To assess the indicator properties of the financial aggregates, we chose monetary components that are published early enough to serve as leading indicators of economic activity. We have thus excluded the broad monetary aggregates (M2+, M3+, ...), which include deposits at near-banks, since these series are available with time lags similar to those for nominal spending.[10] Credit aggregates were also excluded for the same reason.[11]

1.2 The uncertainty level

Figure 1 (see appendix for figures) illustrates the movements of the various variables in our system. A quick analysis reveals some similarities but also some striking differences. The descriptive statistics shown in Table 2 underline this impression.

We could proceed to a classification of the different variables according to certain common features. A first group would include variables determined in auction markets: i.e., the two interest rates, the price of oil, the price of commodities, and the exchange rate. The two real income variables could be grouped in a second set. Lastly, a final group would consist

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[9] This choice ensures that our results will be comparable to those of other studies presented to the Monetary Seminar. However, it is noteworthy that, nowadays, a fair number of researchers argue for the use of non-seasonally adjusted series that are closer to the facts that one wishes to model. Raynauld and Simonato (1990) discuss this question and devise a BVAR methodology that can address seasonal series.

[10] "The broad money aggregate M2+ is not used in the indicator models discussed here because data on deposits at some near-banks are available only with a lag of more than a quarter." (Muller, 1989, p. 5, footnote 10.)

[11] "The bivariate credit indicator models use contemporaneous values of the growth rates of the different credit aggregates which makes them somewhat less valuable than the models using only lagged values, particularly because the household credit aggregates used in some of these models are available with only a lag of about two months." (Muller, 1989, p. 6.)

Table 2
Descriptive Statistics 1970:02-1989:04

	MEAN	STD	RHO1	RHO2	RHO3	RHO4	DUFO
Canada							
BASE	2.00	1.53	0.37	0.42	0.35	0.39	0.00
M1	1.89	1.88	0.22	0.02	0.16	-0.20	0.02
M2-M1	3.15	1.51	0.74	0.57	0.44	0.23	0.00
TXCAN	0.05	1.35	0.19	-0.09	-0.03	-0.04	0.83
TXCHA	0.10	1.57	0.42	0.17	0.23	0.06	0.00
GDPD	1.60	0.89	0.72	0.56	0.48	0.47	0.00
GDP	0.95	0.98	0.30	0.06	0.09	-0.06	0.16
NGDP	2.56	1.18	0.55	0.36	0.25	0.13	0.00
United States							
GNP	0.69	1.04	0.25	0.22	0.01	0.03	0.05
GNPD	1.43	0.65	0.75	0.67	0.62	0.60	0.00
GNPN	2.12	1.04	0.21	0.13	0.03	0.09	0.01
TXUS	-0.01	1.53	0.07	-0.33	0.17	0.03	0.05
World							
RPOIL	0.87	12.93	0.51	0.01	-0.10	-0.12	0.01
RPCOM	0.20	2.28	0.14	0.17	0.06	-0.05	0.69

Note: All the statistics are computed using quarterly rates of growth and are expressed as percentages. MEAN is the estimated mean; STD is the standard error; RHO1,...,RHO4 are the estimated autocorrelation coefficients for lags 1 to 4; DUFO is the p-value of the exact portmanteau test proposed by Dufour and Roy (1985) which assesses if the series under investigation is white noise.

of the nominal variables: the monetary base, M1, M2-M1, the two implicit price deflators, and the nominal income variables for Canada and the United States.

1.3 Auction variables

Compared with the other categories, the auction variables (the two interest rates, the exchange rate, the price of oil, and the price of commodities) exhibit erratic behaviour (see Figure 1). In fact, we get the impression that these variables show the greatest uncertainty.

The price-of-oil and price-of-commodities variables are especially representative of this characteristic. Table 2 shows that their estimated standard errors are among the highest. The real price of oil has the largest variance (standard error equals 12.93) with an up and down pattern in 1973-1974 and 1979-80, an abrupt plunge in 1981-82, and a marked decline in 1986. The behaviour of commodities prices is less irregular, but one can highlight a steep rise at the beginning of the 1970s that is resumed in 1987-88 and an erratic decline in between. In the case of this variable, the Dufour-Roy (1985) test does not reject the null hypothesis of white noise on its first difference (referred to as the random-walk hypothesis hereafter).

Interest rates and the exchange rate are crucial macroeconomic variables. Considered as instruments of monetary policy by some analysts, transmission channels by others, interest rates link the financial, monetary and real markets. The exchange rate is an important open-economy pivot of monetary policy and ensures a close link between the financial and real sides of the two countries concerned.

As we can observe from Table 2, interest rates and the exchange rate have large standard errors (compared to their respective averages). For interest rates, this feature is illustrated by a sawtooth behaviour with well-known peaks in 1974, 1979 and 1981.[12] The exchange rate does not show as much movement and corresponds more closely to a random walk: its reversals are usually quite persistent.[13]

The efficient market hypothesis casts some light on the challenge involved in forecasting auction prices. Table 3 presents the root-mean-squared errors (RMSE) and the Theil statistics resulting from a forecasting exercise conducted with an AR(4) model over the 1980s (one-, four- and eight-quarter horizons). For all horizons, the Theil statistics indicate that a forecast based on a no-change assumption is more accurate than the one produced by an AR(4) model (the only exception being the price of oil on a one-quarter horizon).

We also note that, compared to the RMSEs of the other variables of the system, the RMSEs of the auction variables are very high. For a one-quarter horizon, the RMSEs of these variables are among the seven highest recorded. With the four-quarter horizon, four of the five variables are in the group of the six variables with the highest RMSEs. For this horizon, the U.S. interest rate is predicted with surprising accuracy: its RMSE of 3.48 ranks tenth among all the variables. Finally, the forecasts of three auction variables (the exchange rate and the two world commodities prices) are quite inaccurate on an eight-quarter horizon. For this last horizon, the AR(4) forecasts of the interest rates rank fairly well, even when compared to variables exhibiting a smoother behaviour.

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[12] Even though the two interest rates exhibit similar behaviour, their autocorrelation test results differ greatly. Indeed, the Dufour-Roy test cannot reject the hypothesis that the first difference of the Canadian interest rate is white noise, while this hypothesis is rejected in the case of the U.S. interest rate. We can only suppose at this stage that this difference is due to dissimilar sampling and time-aggregation methods in the two cases.

[13] We could not expect to be able to reject the random-walk hypothesis for the exchange rate, but time-aggregation seems to introduce serious autocorrelation patterns in the first difference of this variable.

Table 3
Forecasting Performance of Univariate AR Models 1980-1987

	Horizon					
	1			4	8	
	RMSE	RMSEA	THEIL	RMSE	RMSE	RMSEA
Canada						
BASE	2.04	8.41	0.71	4.01	6.78	3.33
M1	2.35	9.74	0.96	5.73	8.25	4.04
M2-M1	1.07	4.35	0.37	4.50	10.73	5.23
TXCAN	1.86	7.65	1.08	4.17	5.56	2.74
TXCHA	1.49	6.10	1.03	4.24	8.72	4.27
GDPD	0.42	1.69	0.26	1.76	4.19	2.07
GDP	1.11	4.51	0.84	3.67	5.89	2.90
NGDP	1.03	4.18	0.44	3.84	6.26	3.08
United States						
GNP	1.08	4.39	0.86	3.28	5.57	2.75
GNPD	0.37	1.49	0.27	1.72	4.41	2.18
GNPN	1.14	4.64	0.53	3.44	5.28	2.61
TXUS	2.20	9.10	1.12	3.48	3.68	1.82
World						
RPOIL	9.05	41.42	0.78	29.93	38.59	17.72
RPCOM	1.45	5.93	1.14	4.97	8.03	3.94

Note: RMSE is the usual root-mean-squared error for the indicated forecasting horizon (1, 4 or 8 quarters); RMSEA is the same statistic expressed on an annual basis (compounded rate); THEIL refers to the Theil statistics.

In a forecasting model of the Canadian economy where the emphasis is on the analysis of monetary policy and the forecasting of nominal spending, it is of foremost importance to account for the movements of Canadian and U.S. interest rates and the exchange rate. These variables are the principal channels for the transmission of monetary policy (both foreign and domestic). In addition, data for these variables are released well before data for those variables usually identified as monetary policy objectives. Finally, considering their overwhelming importance over the 1970s and 1980s, the price of oil and the price of commodities can hardly be excluded from any serious macro model.

1.4 Real income variables

Despite their less erratic behaviour (compared to the auction variables), the two real income variables shown in Figure 1 (see appendix) were affected by important cycles in the 1970s and 1980s, especially the 1975 recession in the United States, the marked slowdown in 1980 and the 1982 recession in Canada. A parallel analysis of the behaviour of variables such as nominal spending in the two countries shows an upward, continuous trend. A long-term forecast of real growth should thus be quite accurate. It is much more difficult to predict turning points; no theory currently available gives a complete answer to this problem.[14]

The standard errors of the quarterly growth rates of the two real income variables are fairly large compared to their corresponding means. This feature is especially pronounced for U.S. real income with a quarterly real growth rate of 0.65 (annual rate of 2.8) and a standard error of 1.04. If the U.S. GNP has significant first- and second-order autocorrelation coefficients (Dufour-Roy p-value of 0.05), its Canadian counterpart is very much like a random walk with a quarterly drift of 0.95 (3.8 on an annual basis): the corresponding p-value of the Dufour-Roy test is 0.16.

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[14] Hence, many "expert" forecasters, both in Canada and the United States, kept announcing an imminent recession as early as 1988, while it did not occur until well into 1990.

Despite their sizable standard errors, the real income variables can be predicted fairly accurately as illustrated by the RMSEs of the simple univariate AR(4) models over the 1980s (for all horizons). With RMSEs of less than 4.5 per cent on an annual basis, the two real income variables (U.S. and Canada) belong to the group of six variables with the lowest RMSEs. In terms of the conduct of monetary policy, the problem lies more in the publication time lag, since the forecast uncertainty of these variables is relatively small. Further, a complete multivariate model could well improve upon this forecast performance by taking into account dynamic interrelations between the variables. However, we must consider the almost random-walk behaviour of Canadian real GDP which does not leave much room for strong cross-influences from other variables.

1.5 Nominal and monetary variables

Estimated over the 1970s and 1980s, the standard errors of the monetary variables are fairly low. All the monetary variables have high growth rates, exhibit considerable autocorrelation, and do not display any random-walk type behaviour. The movements of these variables are thus quite smooth. Only the adjusted monetary base and M1 seem to depart from this stylized fact. Not surprisingly, these two variables also have the highest standard errors. Hence, from 1970 to 1989 the quarterly mean growth rate of the base was 2 per cent (8.24 per cent on an annual basis) with a corresponding standard error of 1.53 per cent, while the same statistics are, respectively, 1.89 per cent (7.8 per cent on an annual basis) and 1.88 per cent for M1.

Compared to their respective means, the other nominal variables (M2-M1, the implicit Canadian and U.S. price deflators and nominal spending in the two countries) all have fairly small standard errors. The graphs of these series generally illustrate strong trends with almost indiscernible variations in growth rate.

The relatively small standard errors and strong trends of these variables indicate their low levels of uncertainty. This is confirmed by the predictive performance of the AR(4) models over the 1980s. The two implicit price deflators and the two nominal spending variables are predicted with a high degree of accuracy over all horizons. However, the RMSE of Canadian nominal GDP deteriorates somewhat as the horizon increases. Since this last variable plays an important role in the conduct of monetary policy, this deterioration justifies the exercise conducted for this paper.

The forecasting performances of the monetary variables are less interesting. If we abstract from the M2-M1 result on a one-quarter horizon, the RMSEs of the three monetary variables are usually among the highest of all the variables of the system. The M1 results are especially unsatisfactory. Irrespective of the horizon considered, they improve slightly for the base as the horizon increases, and worsen for M2-M1. The monetary variables are thus characterized by a forecast uncertainty much greater than that of nominal income, the goal variable for which they are supposed to be indicators. In spite of this, the timely availability of the monetary variables warrants their inclusion in a forecasting model. We should thus aim at uncovering the dynamic links between the monetary variables and nominal spending.

2. Justification of the Methodology

2.1 Introduction

As indicated in the introduction, the goal of this exercise is to develop a practical tool to assist the authorities in the short-term conduct of monetary policy. In this respect, two types of models allow for considerable interaction between the variables under study: the traditional structural models such as the Bank of Canada's RDXF and the vector-autoregressive (VAR) models recently proposed by Sims (1980). In both cases, we assume that the structure of the economy can be represented by the following system:

$$D_{11}(L)\, X_{1t} + D_{12}(L)\, X_{2t} = D_1 + e_{1t} \tag{1.1}$$

$$D_{21}(L)\, X_{1t} + D_{22}(L)\, X_{2t} = D_2 + e_{2t} \tag{1.2}$$

where X_{1t} and X_{2t} are k1 and k2 (k1+k2=k) vectors. The associated error terms are e_{1t} and e_{2t} with $Ee_{it}e_{jt}' = \Sigma_{ij}$. $D_{ij}(L) = D_{ij,0}-D_{ij,1}L-D_{ij,2}L^2- \ldots -D_{ij,m}L^m$ $(i,j=1,2)$ are matrix polynomials of order m. Note that in this specification, contemporaneous relationships within and between X_{1t} and X_{2t} can be captured by the $D_{ij,0}$ matrices. As usual, the e_{1t} are part of the structure and correspond to economically meaningful concepts. D_1 and D_2 are vectors of constants. In a more general form, we can write:

$$D(L)\, X_t = D + e_t \quad (t=1, \ldots ,T) \tag{2}$$

where $D(L) = D_0-D_1L- \ldots -D_mL^m$ and $Ee_te_t' = \Sigma$.

We first present structural models and the discussion will focus on their possible limitations in the context of the exercise undertaken in this study.

2.2 Traditional structural models with ex ante restrictions

We do not intend to make an overall judgment on the forecasting performances or the abilities of structural models to analyze policy. Considering their long experience in this area, economists at the Bank of Canada are better equipped to do this. However, we do want to raise a few points. Specifically, it is possible to interpret equation (1.1) in the context of a structural model by assuming the usual dichotomy between endogenous

(X_{1t}) and exogenous variables (X_{2t}). This fundamental distinction results in certain restrictions that are often overlooked (for example, $D_{21}(L)$ and $\Sigma_{21} = 0$). Furthermore, the dynamic structure of these models is generally not very sophisticated and the implied exclusion restrictions have been challenged by Sims (1980). Finally, in a short-term forecasting context, structural models are rather cumbersome and costly to operate.

However, we believe that structural models are plagued by more significant problems - especially if we want to use them to address the questions raised in this seminar. A quick analysis of past and current macroeconomic debates shows that results obtained from structural models depend heavily on their underlying assumptions. This problem is all the more important in the context of the current exercise where the goal is to come up with *short-term* forecasts of certain goal variables and to analyze the *short-term* contribution of some monetary and financial variables to the evolution of these same goal variables. Now, as well as their strong contradictions on the role of money, current leading macroeconomic models also have little to say on the short-term effects of policy variables on goal variables. In an article cited by R.F. Lucas (1990), B. McCallum (1987) alluded to the current consensus in the economic profession on these matters:

> Neither theory nor evidence points convincingly to any of the numerous competing models of the interaction of nominal and real variables. The economics profession does not have a reliable quantitative or even qualitative model of aggregate supply (or 'Phillips curve') behavior. In other words, the profession does not have accurate knowledge of the way in which changes in nominal GNP will be divided, on a quarter-to-quarter basis, between real output growth and inflation.[15]

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[15] Gordon (1988, 1989) presents a completely different view on the reliability of the Phillips curve.

This quotation illustrates the apprehensive stance of the profession on the possible real effects of a monetary policy aimed at price stability. The same quote also puts in perspective the difficult task of understanding the behaviour of the Canadian macroeconomic variables, especially since the adoption of the new policy in 1988. Finally, it indicates the difficulty in forecasting and even analyzing the short-term movements of the macroeconomic variables related to monetary policy.

This lack of unanimity concerning the short-run dynamic links between macro variables necessarily leads to an open empirical approach, as free as possible of any rigid untested propositions. We need to understand not only the impact of money on the target variables, but also the possible channels of transmission of monetary policy.[16] In a research project where the primary objective is not to test competing theories but to forecast and simulate the impact of policy variables, it would be desirable to proceed with a methodology that avoids the imposition of any underlying specific theory. We can thus carry on incorporating many possible theoretical influences and let the data speak for themselves, rather than imposing our preconceived views of the world on the model. We will see that the BVAR models perform best in this type of environment.

2.3 Atheoretical models and forecasting

Litterman (1986, p. 27) recently described the forecasting exercise in the following way:

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[16] In this respect, Plosser (1989, p. 70) asserted recently: "The nature and magnitude, however, of the fluctuations and responses in the real neoclassical model mean that real business research poses a challenge to conventional views regarding the relative importance of money. This is particularly true given the difficulties economists have faced in developing a convincing and coherent explanation of the monetary transmission mechanism." For an opposite viewpoint, see Laidler (1990).

> One way to think about this problem is to view the forecasting equation as a filter that must pick out from the din of economic noise a weak signal that reveals the likely future course of the variable of interest.

In this exercise, the structural models tend to specify the channels of influence of different variables and the paths and dynamics of the interactions by excluding certain variables. Considering the relative imprecision of current macroeconomic models regarding the short-term dynamic relationships between the variables, atheoretical models avoid unnecessary restrictions and allow for the influence of a relatively large set of variables on the variables to be forecasted.

2.4 Vector-autoregressive models (VAR)

Sims (1980) put forward the vector-autoregressive methodology with no *a priori* restrictions. It can be viewed as a reduced-form relation where each variable is linked to its own past values as well as the lagged values of all the other variables in the system.

In general, VAR models correspond to the reduced form of equation (2):

$$H(L)\,X_t = H + u_t \qquad (t=1, \dots T) \qquad (3)$$

where $H(L) = D_0^{-1}\,D(L)$, $H=D_0^{-1}D$ and $u_t=D_0^{-1}e_t$; u_t is constructed as a linear combination of structural errors e_t and can no longer be interpreted from an economic viewpoint. It is centred on zero with a variance-covariance matrix given by $\Omega=D_0^{-1}\Sigma D_0^{-1'}$. Linearity of the postulated relationships is the sole maintained hypothesis of VAR models; no arbitrary exclusions are made and the complete dynamics are investigated.

In this relatively free formulation, VAR models impose relatively few constraints, which usually requires the estimation of a large number of parameters, thus rapidly exhausting the available degrees of freedom. For large models like the one considered in this paper, some restrictions are required; for example, one would then have to exclude potentially important variables or restrict the number of lags. As well, large, unrestricted regressions often suffer from "over-parameterization" and lead to poor forecasts: with a large number of parameters, the researcher picks up fundamental as well as sample-specific and temporary relationships, the latter being the source of the poor performance outside the sample period.[17] This fundamental problem was faced by Burbidge and Harrison (1985), Kuszczak and Murray (1987), Ambler (1989) and Johnson and Schembri (1989) in their application of the VAR methodology to Canadian data.

2.5 Bayesian vector-autoregressive models (BVAR)

To overcome the problems associated with VAR models, Litterman (1979), Doan, Litterman and Sims (1984), and Sims (1989) suggested the incorporation, in a Bayesian fashion, of relevant *a priori* information in the estimation. *A posteriori* estimates obtained after combining priors and sample information are the cornerstone of Bayesian VAR models.

Here, we use the Kalman filter framework proposed in Doan, Litterman and Sims (1984), and Sims (1989) but, for presentation purposes, follow Harvey (1981) to simplify and unify the notation. All the coefficients of a given VAR equation are stacked in the vector α_t with individual elements $h_{j,\ell}$ ($\ell = 1, \ldots, m$, $j = 1, \ldots, k$) and h_0 (the constant); in fact, the first m coefficients correspond to the first variable, then subsequent m coefficients correspond to the second, etc. Since α is indexed by t, this formulation implies that the VAR coefficients $h_{j,\ell}$ are now time-varying (for ease of exposition, the individual coefficients will not be indexed by t). We have a pair of measurement and transition equations corresponding to each equation of the VAR model:

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[17] In a recent article, Kennedy (1989) deals with this problem and shows, in the context of a model of the U.S. economy, how the inclusion of *a priori* information can be useful.

$$y_t = Z_t\alpha_t + \xi_t \tag{4.1}$$

$$\alpha_t = \alpha_{t-1} + n_t \qquad (t=1, \ldots T) \tag{4.2}$$

where y_t is the dependent variable and Z_t is a vector of all the right-hand variables (the lagged values of all the variables of the system plus the constant term). For example, for the first VAR equation, $y_t = x_{1t}$ and $Z_t = [x_{1t-1}, \ldots, x_{1,t-m}, \ldots, x_{kt-1}, \ldots, x_{kt-m}, 1]$. By providing a convenient set of recursive predictions and updating equations (see Harvey, 1981), the Kalman filter framework fits most forecasting tasks nicely. However, to start the Kalman filter iterations and obtain the Minimum Mean Square Linear Estimator (MMSLE) predictions of y_t given information available at t-1, we have to specify the initial α_0 (more precisely, its mean a_0 and its associated variance-covariance matrix P_0), as well as Q, the variance-covariance matrix of n_t. For simplicity, it is assumed that the scalar σ^2, the variance of ξ_t, is a known fixed quantity (to be replaced in practice by the estimated variance of a fixed-coefficients autoregressive model for variable y). The vector a_0 and the matrices P_0 and Q will be referred to loosely as the initial *a priori* information.

Following Litterman, these priors are not based on economic theory but rest on some empirical regularities. For example, according to Litterman (1979) and Nelson and Plosser (1982), most macroeconomic variables can be approximated by the simple discrete random-walk model with drift. For a representative equation i of system (1), this takes the form

$$X_t = h_0 + X_{t-1} + u_t \,. \qquad (5)$$

More specifically, the prior mean a_0 for the i^{th} equation will be centred on the elements $h_{j,\ell}$ ($\ell = 1,...,m$; $j = 1,...,k$) equal to 1 for $j = i$ and $\ell = 1$, and 0 otherwise.[18]

At first glance, this information appears to be rather restrictive and may not be appropriate to all the series investigated. The degree of constraint will depend on the dispersion associated with each coefficient. Ideally, this *a priori* uncertainty should reflect some basic requirements. In addition, the procedure chosen should be practical since it would be impossible to determine (separately) the values of the coefficients. To meet these requirements, Sims (1989) suggests the following general formulation:

$$\text{SQRT}\ \{\ \text{VAR}\ [h(j,\ell)]\ \} = \text{TIGHT} \cdot \text{OTHER} \cdot D(\ell) \cdot (\hat{\sigma}_i/\hat{\sigma}_j) \qquad (6)$$

where

TIGHT	is the overall tightness parameter. It is the standard deviation of the coefficient of variable i in equation i lagged once, e.g., X_{t-1} in equation (5).
OTHER	allows the imposition of a tighter standard error on the j^{th} variable in equation i; it operates only when $i \neq j$.
D(ℓ)	is a distributed-lag function that tightens the standard errors as the lag length increases. We use the harmonic specification $g(\ell) = \ell^{-DECAY}$ where DECAY is a constant. Note that $D(1) = 1$.
$\hat{\sigma}_i/\hat{\sigma}_j$	adjusts the *a priori* information to the relative scale of the variables where $\hat{\sigma}_i$ is the estimated standard error of a univariate AR model for variable i and $\hat{\sigma}_j$ is the same statistic computed for variable j.

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[18] In practice, h_0 is set to zero but since its initial prior is kept loose, we will eventually get the form described by equation (4).

The standard error associated with the constant term is given by

$$\mathrm{SQRT}\{\mathrm{Var}[h_0]\} = \mathrm{TIGHT} \cdot \mathrm{CONREL} \cdot \hat{\sigma}_i \tag{7}$$

and is thus proportional to the standard error of the error term of the left-hand-side variable i. Finally, the variance-covariance matrix of the disturbance n_t of the transition equation is set to

$$Q = \mathrm{TVAR}^2 \, P_0 \tag{8}$$

and is proportional to P_0. Q controls the speed at which the coefficients are allowed to change over time. The initial priors are thus functions of the so-called hyperparameters [TIGHT, OTHER, DECAY, CONREL, TVAR] which are usually treated as unknown constants.

2.6 Estimation strategy

Sims (1989) estimates these unknown parameters by maximizing the likelihood function but argues that "maximum likelihood is justifiable only as an approximation to a Bayesian procedure or as a device for summarizing a likelihood function" (p. 13). More precisely, the log-likelihood (excluding constants) of the representative equation can be written as

$$\mathrm{Log}\ L(y) = -\tfrac{1}{2}\sum_{t=1}^{T} \log f_t - \tfrac{1}{2}\sum_{t=1}^{T} v_t^2/f_t \tag{9}$$

where $v_t = y_t - y_{t/t-1}$ and f_t is the variance of v_t (see Harvey, 1981, p. 14). In fact, Sims maximizes the sum of the k individual likelihood functions ignoring, for computational reasons, the covariance between the error terms of the different equations. It is interesting to note that the last term of equation (9) consists of the sum of one-step-ahead forecast errors squared-weighted by their variance. Large errors will not penalize the likelihood as long as they are associated with large variances.

As an alternative estimation procedure, Doan, Litterman and Sims (1984) seek hyperparameters that minimize the sum of the root-mean-squared errors over the system of k equations. This criterion thus consists of a sum of unweighted forecast errors and was also retained in most BVAR applications.

2.7 Auction markets

A BVAR model will often include variables determined in auction markets (treasury bills, the exchange rate, etc.) and these must be given special treatment. For example, instead of using a discrete random-walk prior, Sims (1989) proposed a discrete specification resulting from time-averaging a random-walk process operating on a shorter interval. Indeed, if the true random-walk process is defined over a daily interval (or weekly), but the estimations are carried out on quarterly averages, we will get, approximately, the coefficients given by the AR representation (in levels) of an ARIMA(0,1,1) model with a moving-average coefficient equal to 0.2679. For the m=4 case, the prior mean given by equation (5) is thus replaced by

$$\begin{aligned} X_t = {} & h_0 + 1.2679\, X_{t-1} - 0.3397\, X_{t-2} + 0.0910\, X_{t-3} \\ & - 0.0244\, X_{t-4} + u_t\,. \end{aligned} \tag{10}$$

In fact, Sims (1989) uses this form of prior for all the variables in his BVAR system and reports interesting improvements in forecast performances; we will follow the same strategy. In addition, the auction nature of these series implies a behaviour that is often independent of observed past information. Consequently, it is preferable to introduce additional tightening around the initial prior mean. Specifically, if we have such a left-hand variable, we will set the prior as

$$\mathrm{WIENER}^2\, P_0\,. \tag{11}$$

2.8 Cointegration

As specified, Canadian and U.S. interest rates are each associated with a random-walk prior. Following a shock, lasting divergences could be observed - a characteristic at odds with Canadian-U.S. historical evidence. The rather harmonious monetary policies followed in the two countries have led to a form of parity of nominal interest rates, at least in the long term. This kind of dynamic behaviour has been studied extensively by Engle and Granger (1987) in the context of cointegrated models. This is the methodology we have used in our BVAR specification of the behaviour of Canadian and U.S. interest rates.

Two series are cointegrated if they obey the following two conditions: (i) each series has a unit root; and (ii) their long-run behaviour is closely related (they have a common unit root). The prior means corresponding to the Canadian and U.S. interest rates are given by

$$\mathrm{TXCAN}_t = \mathrm{TXCAN}_{t-1} + u_{\mathrm{TXCANt}} \tag{12.1}$$

$$\mathrm{TXUS}_t = \mathrm{TXUS}_{t-1} + u_{\mathrm{TXUSt}} \tag{12.2}$$

and satisfy the first cointegration condition. However, even if the BVAR methodology allows other variables to influence Canadian interest rates, the impact is usually much too tenuous to satisfy the second condition, especially for the two interest rate variables as illustrated in Figure 1. To account for this important feature, we have replaced the prior mean (12.1) by

$$TXCAN_t = (1\text{-}COINT)\ TXCAN_{t-1} + (COINT)\ TXUS_{t-1} + u_{TXCANt} \qquad (13)$$

where COINT is a new hyperparameter to be estimated. This formulation downplays any persistence displayed by the Canadian interest rate (the own coefficient will be less than one) and links it more directly to the U.S. dynamics.

2.9 Other considerations

The matrix P_0 specified so far is diagonal, implying that we have not introduced any covariance terms. This practical independence assumption implies a much higher degree of uncertainty for the forecasts of the left-hand variable than our random-walk prior mean usually delivers in practice. To adjust for this feature, Sims (1989) introduced an intuitive and simple procedure based on a *dummy* observation (the reader is referred to Sims (1989, p. 8) for a complete discussion of this feature). After setting up the initial prior matrix P_0, we use the model to forecast the period $t=m+1$, replace the actual values of the series at $t=m+1$ by the forecasts multiplied by a scale factor DUMMY, and do one pass of the Kalman filter. Since no forecast errors are made, the Kalman filter makes the posterior mean the prior mean but proceeds to some adjustments to the posterior variance, essentially by introducing small off-diagonal elements. The DUMMY parameter is expected to be close to 1. The dummy Kalman operation should be seen as a practical way of introducing off-diagonal elements in the dispersion matrix P_0. In fact, this dummy forecast setup can be used as a general way to impose restrictions in a BVAR framework since it operates in a manner similar to the artificial observations of the Theil-Goldberger mixed-estimation procedure.

2.10 Some qualifications

So far, we have highlighted the more positive properties of BVAR models, but one must not ignore the drawbacks. For instance, we have emphasized that these models avoid the necessity of imposing exclusion restrictions. This is true only to a certain extent. The choice of the variables entering the vector X is, in itself, an exercise of elimination. Considering the current sample size of the macro series, only a limited number of variables can be included in the specification. In the case of an open economy such as Canada's, the problem is even more significant; we may lose a certain number of observations owing to the change of exchange rate regime and foreign variables must be included, limiting *de facto* the list of domestic variables included in the system. However, for a small open economy like Canada, it is reasonable to assume that U.S. variables are strictly exogenous, a feature that could be exploited in the estimation.

Despite the use of *a priori* information, the BVAR models are fairly open and can pick up many interactions, some of them sample-specific. The forecasting performance of the model or the policy analysis exercises could thus be impaired by this over-generous inclusion principle.

BVAR models are distinguished by their reliance on *a priori* information. However, there is no unique universally accepted set of priors. Based on experience and ingenuity, each researcher can tailor the information to the problem at hand. For example, Todd (1984, p. 22) has indicated:

> When an explicitly Bayesian approach is used, it becomes clear that the modeler is free to take prior beliefs from many sources and cast them into many forms. Therefore it is impossible to speak of a unique Bayesian or even BVAR approach to forecasting.

Consequently, BVAR modelling, like most empirical methodology, requires a great deal of experimentation and calibration before a model suitable for forecasting and policy analysis is obtained. There is no magic formula appropriate for all circumstances. If the model is to generate useful results, we must be able to "harness" all the *a priori* information.

BVAR models have been used primarily for forecasting and policy analysis with U.S. data (Litterman, 1980, 1984, 1986; Todd, 1984; Doan, Litterman, and Sims, 1984; Sims, 1989). The results compare quite favourably with those obtained from structural models; this is especially encouraging since BVAR models are less costly to operate when used on a regular basis.[19] Raynauld (1987, 1988, 1989) and Raynauld and Racette (1989), have used this methodology to model Canadian *regional* cycles, but as far as we know, there is no working BVAR model of the Canadian economy. The present study should thus be viewed as a first experiment on Canadian macroeconomic series with such a methodology. We are particularly pleased that this exercise could be conducted in the context of the Monetary Seminar sponsored by the Bank of Canada and may possibly be useful in the conduct of monetary policy. This is the ideal forum for such experimentation.

Despite these qualifications, we believe that the BVAR experiment reported here is worthwhile if it serves to assess the real forecasting ability of these models with regard to the conduct of monetary policy. We will show, however, that the model can also be used for policy analysis, as well as to assess results obtained with bivariate or multivariate models based on simple correlations. BVAR models are a valuable alternative to the traditional forecasting and policy analysis models. It is a low-cost methodology free of

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19. It is noteworthy that forecasts from the BVAR methodology are a good basis for comparison since they are derived mechanically without any judgmental adjustment on the part of the forecaster. (See McNees, 1986 and Litterman, 1985.)

stringent theoretical restrictions, yet able to incorporate generally accepted *a priori* information.

3. Estimation and Forecasting Results

3.1 Basic estimation information

The objective of the BVAR model is to account for the movements of seven Canadian variables (BASE, M1, M2-M1, TXCAN, TXCHA, GDPD, and GDP) taking into account the international environment captured by three U.S. variables (GNP, GNPD and TXUS) and two real prices (RPOIL and RPCOM). At this stage, two empirical strategies are available, both exploiting the assumption that the last five foreign variables are strictly exogenous, i.e., the Canadian variables have no impact on these variables. The first setup implies two separate models: one Canadian BVAR model with exogenous variables:

$$H_{11}(L)\ X_{CANt} = H_{CAN} + H_{12}(L)\ X_{USt} + u_{CANt} \tag{14.1}$$

where

$$H_{12}(L) = H_{12,0} + H_{12,1}L + \ldots + H_{12,m}L^{m},$$

and one U.S. BVAR model:

$$H_{22}(L)\ X_{USt} = D_{US} + u_{USt}\ . \tag{14.2}$$

This setup incorporates the current exogenous foreign variables in the Canadian equations. In a forecasting situation, those current values are, of course, unknown and will be predicted by model (14.2). The Canadian residuals (u_{CANt}) will thus be purged of any current foreign influences and will correspond to domestic factors only.

The second setup leads to the estimation of only one BVAR model

$$H(L)\,Xt = H + u_t \tag{15}$$

with the hyperparameter OTHER taking the value of 0.00' when Canadian variables enter foreign equations (to preserve the exogeneity assumption). In this formulation, only lagged foreign variables appear in the Canadian equations. However, the contemporaneous correlations will be captured by the variance-covariance matrix of the residuals u_t and could easily be recovered. For technical reasons to be detailed further, the first setup has been used to estimate the hyperparameters, while policy exercises were conducted with the second formulation.

Table 4
Hyperparameter Estimates: 1971:01-1987:04

TIGHT	0.1486
OTHER	0.5332
DECAY	0.9229
CONREL	3.1118
TVAR	0.0160
WIENER	0.0951
COINT	0.4971
DUMMY	0.6142
RMSE SUM	0.2641

Let us first summarize our BVAR apparatus. The prior means are based on a discrete time-averaged random walk except for Canadian interest rates. The Canadian interest rate variable was treated in a special way since it is, by assumption, cointegrated (COINT) with U.S. interest rates. Since the exchange rate, the real price of oil and the prices of commodities are considered to be speculative variables, their *a priori* variance is multiplied by the WIENER parameter. With TIGHT, OTHER, DECAY, CONREL, TVAR, and DUMMY, we have eight hyperparameters to estimate. Since we have twelve explanatory variables with four lags for each variable, a constant, and a postal strike dummy (see the appendix), each equation has a total of 50 right-hand variables (Z_t). Actual estimation was for the period 1970:01 to 1987:04; we kept the 1988:01-1989:04 period for an *ex ante* forecasting exercise. All computations were carried out with RATS 2.0.

We followed the strategy used by Doan, Litterman and Sims (1984), and searched for the values of the hyperparameters that would minimize the sum of the k one-step-ahead root-mean-squared errors (the v_t's of equation (9)). To find the best values, we first used BAYESMTH (Sims, 1984), an optimization algorithm especially designed for cases where the function evaluations are time-intensive (as in most Kalman-filter estimations) but also proceeded to some grid-search evaluations. Compared with an unrestricted VAR model, we get improved forecasting performances (the RMSE sums are, respectively, 0.6056 and 0.2641).[20] The hyperparameter estimates for TIGHT (0.14), WIENER (0.09), DECAY (0.92), CONREL (3.11), DUMMY (0.61) are broadly in line with published work in this area.[21] The TIGHT and WIENER values suggest a relatively tight system for the auction variables. The value taken by OTHER (0.53) is relatively loose, a feature that can be explained by the inclusion of the important U.S. variables. With an estimate of TVAR = 0.01, we detected little time variation (of course, the sample period is relatively short) and policy evaluation exercises can be safely conducted. Finally, as suspected, the COINT (0.49) coefficient reflects very close links between Canadian and U.S. interest rates.

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[20] The unrestricted VAR model is in fact a BVAR model with loose priors with TIGHT = 10.0, OTHER = 1.0, DECAY = 0.0, CONREL = 10.0, DUMMY = 0.01, TVAR = 0.0001, WIENER = 1.0 and COINT = 0.5.

[21] Using similar U.S. series over the 1949:03-1987:02 period, Sims (1989) reports the following values: TIGHT = 0.17, OTHER = 0.19, DECAY = 1.08, CONREL = 2.97, DUMMY = 1.16, WIENER = 0.37, and TVAR = 0.10. However, it is not possible to proceed to a strict comparison since Sims used a broader BVAR setup taking into account ARCH effects and non-normal error terms.

3.2 Interactions among variables

While the estimation results obtained with the model at this stage can only be considered as correlations, it is worth noting the interactions revealed by the analysis of the coefficients estimated over the 1970-87 period with the BVAR models just described. Furthermore, they will be an important ingredient in the policy simulation exercises. Following Sims (1980), properties of BVAR models are usually investigated in terms of IMPULSE response coefficients given by

$$X_t = u_t + \psi_1 u_{t-1} + \psi_2 u_{t-2} + \dots \tag{16}$$

where the ψ_ℓ matrices are calculated recursively from the H_ℓ ones. $\psi_{ij,\ell}$ gives the impact after ℓ periods of a one-standard-error shock of variable j on variable i. The results are illustrated in Figures 2.1 and 2.2 (see appendix) and show the dynamic interactions between variables over a 32-quarter period. For instance, the graph on the 2nd line, 1st column of Figure 2.1 shows $\psi_{21,\ell}$ and illustrates the impact of a BASE shock on M1. Similarly, the graph on the 7th line, 1st column of Figure 2.2 shows $\psi_{78,\ell}$ and illustrates the impact of a U.S. GNP shock on Canadian output.[22] As indicated previously, being reduced-form errors, the u's cannot lead to any economic interpretations. For example, an M1 shock cannot be associated with a single source; it could be the result of demand, supply or multiplier shocks.

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[22] We do not present the impact of Canadian variables on U.S. ones since, as mentioned above, they have been constrained, for all practical purposes, to zero.

An overall analysis of the two figures leads to the following comments:

- Few Canadian shocks are persistent. Only the exchange rate and real Canadian income shocks have lasting effects, a feature easily explained by the random-walk nature of these series. The interest rate shock is the least persistent.[23] Further, the exchange rate does not show much reaction to other shocks, the only sizable influences come from real commodities prices.

- On the foreign side, the U.S. real income and price shocks, as well as the two real commodities prices, are very persistent. The U.S. interest rate shock dampens after two or three quarters. If we consider only the U.S. variables, the patterns are very much in line with the results published by Sims (1986) using a six-variable model of the U.S. economy.

- The monetary variables (BASE, M1, and M2-M1) are quite closely related but do not exert any sizable influence on Canadian non-monetary variables (real income, prices, the exchange rate, or even the interest rate or prices). Similarly, the non-monetary variables have a very weak impact on the monetary variables, M1 being the monetary aggregate that is affected most.

- In contrast, foreign shocks have a surprisingly persistent and strong impact on the Canadian monetary variables. The U.S. interest rate has the weakest impact.

- Foreign shocks generally have a much stronger and lasting influence on Canadian variables than the Canadian shocks.

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[23] A cynical mind would use this lack of persistence to interpret the short-lived January 1990 29-basis-point drop in the treasury bill rate. More seriously, the absence of persistence is reassuring given the fact that the BVAR methodology centres the process of all variables on the random-walk prior. This shows how the methodology leaves ample room for the true statistical processes to come out despite the *a priori* information that is suggested at first.

The above points illustrate how a complete macro model can put in perspective the simple bivariate or multivariate correlation results obtained at the Bank.

Bearing in mind that the figures illustrate reduced-form correlations, we now turn to a more detailed analysis of individual shocks:

- The effects of BASE, M1 and M2-M1 shocks are fairly standard. We find a positive correlation between M1 shocks and Canadian real income. This correlation was also obtained in the indicator studies done at the Bank where real M1 was found to be the best predictor of real GDP.
- A positive interest rate shock can be associated with an M1 contraction and a weak surge in M2. It is also related to a drop in real GDP.
- The very persistent depreciation of the Canadian dollar (Figure 2.1, 5th column) parallels a fall in real GDP, a result at odds with theoretical conclusions but understandable given the period under examination. Depreciations of the Canadian dollar were often observed in slowdown periods (for example, the depreciation at the end of the 1970s occurred when the growth rate was declining), while the appreciation witnessed after 1986 coincided with a period of healthy real growth.[24]
- The negative correlation between a price shock and the monetary variables is surprising. However, this negative influence turns positive quite rapidly. Furthermore, Kuszczak and Murray (1987), in their VAR model of the Canadian economy over the 1970:03-1984:04 period, estimate a negative and statistically significant sum of the coefficients of lagged prices on M1. Even if the result we get is at odds with standard theory, we do not constrain it to be positive. We think a free specification is the best way to uncover unforeseen channels and to come up with solutions to the puzzles encountered in the conduct of monetary policy.

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[24] Johnson and Schembri (1989) get similar results over the 1971-86 period. See their matrix A_0 on p. 18 which shows contemporaneous relations between shocks to the different variables of their system.

- Real Canadian GDP is not strongly affected by Canadian shocks, but is very sensitive to foreign disturbances.

- The links between the various U.S. shocks and the other variables of the system are usually as expected. Notice the strong reaction of Canadian real GDP and prices to their U.S. counterparts. A U.S. interest rate shock is followed by a series of responses easily understandable in terms of theory, but we prefer to leave it as reduced-form correlations. The surge in U.S. prices following a shock to U.S. interest rates stands out as a peculiar result, but Sims (1986) also obtained the same correlation.

- While the effects of a commodities price shock are as expected, the impact of an oil price shock is surprising. According to the estimates, Canadian prices seem to decline following an increase in oil prices. All the Canadian monetary variables follow a similar pattern after the same shock. However, since we have not disentangled the supply, demand, policy, and balance of payments reactions in this complex scenario, we cannot interpret this result at this stage of the analysis.

3.3 Forecasting performance of the BVAR model over the 1980s

Table 5 shows the forecasting performance of the BVAR model in terms of Theil (one-period horizon) and RMSE (one-, four- and eight-period horizons) statistics over the 1980s. To the twelve variables of the model, we added two additional ones (as in Table 3), namely the nominal expenditures of the two countries constructed from real incomes and the implicit price deflators. For comparison purposes, the discussion will refer to the forecasting results of the simple AR(4) models discussed in Section 1 (also given in Table 3).

Overall, the dynamic interrelations lacking in AR models but captured by the BVAR methodology, lead to improved forecasts (compared to AR models) - at least over the 1980s. The exceptions (9 of the 42 variables) are mostly foreign variables that are not central to our exercise. These are: the real price of oil (on all horizons), the exchange rate and the U.S. interest rate on the four- and eight-quarter horizons, U.S. nominal expenditure eight

Table 5
Forecasting Performance of the BVAR Model: 1980-1987

	Horizon					
	1			4	8	
	RMSE	RMSEA	THEIL	RMSE	RMSE	RMSEA
Canada						
BASE	2.10	8.67	0.74	3.34	4.76	2.35
M1	1.98	8.16	0.81	5.28	7.45	3.66
M2-M1	0.95	3.85	0.33	3.60	7.82	3.84
TXCAN	1.51	6.18	0.87	3.80	5.29	2.61
TXCHA	1.45	5.93	1.00	4.47	9.11	4.46
GDPD	0.41	1.65	0.26	1.57	3.02	1.50
GDP	0.85	3.44	0.65	3.19	5.89	2.90
NGDP	0.75	3.03	0.32	3.29	4.73	2.34
United States						
GNP	1.02	4.14	0.81	2.60	4.47	2.21
GNPD	0.35	1.41	0.25	1.49	3.63	1.80
GNPN	1.10	4.47	0.52	3.26	5.57	2.75
TXUS	2.11	8.71	1.08	3.91	5.51	2.72
World						
RPOIL	10.08	46.84	0.87	31.15	40.24	18.42
RPCOM	1.20	4.89	0.95	4.15	7.40	3.63

Note: RMSE is the usual root-mean-squared error for the indicated forecasting horizon (1, 4 or 8 quarters); RMSEA is the same statistic expressed on an annual basis (compounded rate); THEIL refers to the Theil statistics.

quarters ahead and, finally, the monetary base on a one-quarter horizon. The monetary base and exchange rate results warrant some comment. Given the near random-walk property of the exchange rate, the one- and two-year horizon results are not surprising. Further, the BVAR RMSE statistics are only marginally higher than those of the AR model (close to 5 per cent larger). For the monetary base, the difference between the two RMSEs is 3 per cent for the one-quarter horizon but narrows considerably and even favours the BVAR model as the horizon lengthens.

We now discuss the results in more detail with particular emphasis on the Canadian variables. Cast on an annual basis, the RMSE statistics of all the variables usually improve as the horizon lengthens.[25]

Based on the RMSEs, the two implicit price indices are the easiest variables to forecast, regardless of the horizon.[26] The one-quarter-ahead Theil statistics clearly illustrate the gain achieved by the BVAR with respect to the no-change forecast. The RMSEs obtained by these two variables are way below those of the other variables (always less than 2 per cent on an annual basis and for all horizons) and the gap between the AR and BVAR results widens as the horizon increases. For example, the eight-quarter BVAR RMSE for the Canadian implicit price index is 28 per cent lower (1.5 per cent compared to 2.07 per cent) than that of the AR model.

Canadian nominal GDP, U.S. GNP and real Canadian GDP can be placed in a second group. For these three variables, the annual RMSE statistics are usually low, at least compared to those of the other variables in the system: the 4 per cent one-quarter-ahead result improves to less than 3 per cent on a two-year horizon. It is especially encouraging to see that Canadian nominal GDP could be predicted with such accuracy, improving upon the AR performance by more than 14 per cent on all horizons considered.

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[25] The only exception to this pattern is the U.S. implicit price deflator which has, however, very low RMSEs.

[26] One must note that our forecasting results for the three U.S. variables generally compare favourably with those presented elsewhere in the literature. See, for instance, McNees (1986) and Litterman (1986) who compare results from 6 or 7 variable BVARs to those of well-known structural models.

For the monetary variables (BASE, M1, M2-M1), the BVAR results, although interesting, are not as decisive. The M2-M1 one-quarter-ahead RMSE of 3.85 per cent performs fairly well with respect to the other variables, but this performance cannot be maintained as the horizon lengthens: while the annual RMSE of the other variables of the system improves as the horizon increases, the M2-M1 statistic remains the same at 3.9 per cent. Conversely, the forecast performance of the monetary base improves over the time horizon. For example, the relatively high 8.7 per cent figure for the one-quarter horizon drops appreciably to 2.3 per cent for the eight-quarter case. The relative forecasting performance for M1 is one of the worst (always near the 11th position) but the RMSE nevertheless improves from 8 per cent to 3.7 per cent as we move from the one-quarter to the eight-quarter horizon.

For the Canadian short-term interest rate, we get a forecasting performance close to the average with a slight improvement over the AR model and a downward RMSE path (6.2 per cent to 2.6 per cent) as the horizon lengthens. Finally, as expected, the exchange rate stands out as the most difficult variable to forecast with a 4.5 per cent RMSE statistic on all horizons.

Overall, for the 1980s, the BVAR model does very well in forecasting the goal variables of monetary policy - the GDP price deflator, nominal GDP and, to a lesser extent, real GDP. In addition, the relatively less precise results for the monetary variables over the very short term, (compared to the goal variables) are acceptable on a longer horizon. As already indicated, the early availability of the monetary aggregates is a desirable characteristic that can be exploited in an *ex ante* current-quarter forecast of the goal variables.

4. Analysis of the Dynamic Interactions

4.1 Uncovering structural shocks

Except for a few well-defined cases, the u_t shocks underneath the Ψ_ℓ impulse response matrices (see equation (16)) do not yield any economic interpretations. The motivation is well known and can be found in any standard econometric textbook. In most cases, these shocks are linear combinations of unobservable structural shocks. Under certain conditions, Sims (1986) and Bernanke (1986) have shown that it is possible to recover the e's by exploiting the relationship

$$D_0 u_t = e_t \tag{17}$$

implicit in the BVAR reduced-form specification. The general problem lies in estimating the $[(k \cdot k)\text{-}k]$ coefficients of the D_0 matrix and the k variances of Σ (the structural shocks are assumed to be orthogonal) from the $(k \cdot (k+1)/2)$ estimates of Ω, the variance-covariance matrix of the BVAR residuals. As usual, we have to make sure that the number of parameters estimated is less than or equal to the number of elements in matrix Ω. We have used a RATS procedure written by Doan (1990) where the estimates are chosen to ensure that $D_0^{-1}\Sigma D_0^{-1'}$ corresponds as closely as possible to Ω. Simple examples of this type of estimation can be found in Sims (1986), Bernanke (1986), Blanchard (1989) and Johnson and Schembri (1989).

This generic procedure could not be applied to our specific problem. Since we have 12 equations, our Ω matrix contains 78 elements, a number much higher than in previous applications. This led to numerous problems as the restrictions imposed were repeatedly rejected by the data. We then decided to follow a different procedure, more appropriate to the problem at hand.

Given the realistic block-exogeneity structure of our model, this problem can be decomposed into three smaller problems. First, we can estimate a Canadian BVAR model with U.S. current exogenous variables (see equation 14.1). According to Gordon and King (1982), the estimates of $H_{12,0}$ give the impact on Canadian variables of U.S. shocks u_{USt} (note u_{USt} and not e_{USt}). Second, since the estimated residuals of this new BVAR model will thus be purged of any current U.S. influences and will now correspond to domestic factors only, we can proceed to the estimation of a contemporaneous Canadian model corresponding to the (7x7) upper portion of the matrix Ω of the residuals of model (16). More precisely, we will investigate the relationships given by

$$D_{11,0}u_{CANt} = e_{CANt} \cdot \qquad (18)$$

Third, given the block-exogeneity assumption, the U.S. structural shocks will be uncovered from the foreign residuals of the BVAR model exploiting:

$$D_{22,0}u_{USt} = e_{USt} \cdot \qquad (19)$$

This corresponds to the lower right-hand-side (5x5) portion of the matrix Ω.

To sum up, the policy analysis exercise will be conducted in the following manner:

- One standard-error structural U.S. shock will be given by $(D_{22,0})^{-1}SQRT(\Sigma_{22})$ and the impact will go through the U.S. economy in the usual way. The current influence on the Canadian economy will be amplified by $H_{12,0}$.
- The Canadian shocks of one-standard-error magnitude will be given by $(D_{11,0})^{-1}SQRT(\Sigma_{11})$.

4.2 Identification and estimation of the contemporaneous model

The BVAR Canadian residuals (of the model with current foreign variables) were used to calculate the (7x7) upper portion of the reduced-form variance-covariance matrix Ω (see Table 6). From these correlations and with the help of some identifying restrictions, we must estimate a set of equations expressing the contemporaneous interactions between innovations to Canadian variables, i.e., $D_{11,0}$. The estimation method is nonlinear and we must ensure that the estimation converges, that the overidentifying conditions are satisfied and, finally, that the values of the parameters do not get out of hand. The structural model that appears in Table 7 must thus be examined bearing all these aspects of the methodology in mind.

In this context, it is impossible to get totally well-behaved and easy-to-interpret equations for all the variables. The estimated equations do not correspond to specific functions suggested by a well-defined theory. Still, we risk a possible interpretation.[27] When analyzing the results, one must not forget that the model is truncated. Again, we have purged all Canadian innovations from any contemporaneous U.S. influence, postulating, realistically we think, that any correlation between a U.S. and a Canadian variable expresses a causality running from the United States to Canada. The U.S. current shocks will play a role in the full simulation of the model.

The innovation in Canadian GDP is not influenced contemporaneously by any of the other Canadian innovations. We can thus interpret this disturbance as a Canadian supply shock. As for innovations in the GDP price deflator, they are driven (positively) by innovations in the two components of

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[27] Given the nonlinear process that we use and the convergence problems we face, we cannot offhandedly impose a theoretical structure on the data (i.e., the forecast errors from the BVAR model). If one tries too hard to force the system to a particular structure, one is liable to get nonsensical results or a system that does not converge. For instance, when we tried to get rid of the negative coefficient of the price shock in the M2-M1 equation, other coefficients got out of hand or we were not able to estimate some of the standard errors.

M2 and (negatively) by innovations in real income. The residuals of this equation can thus be associated with demand disturbances.

Exchange rate innovations are influenced by innovations in (M2-M1), and the interest rate. The signs of the coefficients of these two innovations are positive and are easily interpreted in terms of the monetary model of the exchange rate. However, innovations in the GDP price deflator could not be left out of the equation and appear with a negative coefficient. A positive innovation in prices thus seems to lead contemporaneously to an appreciation of the Canadian dollar. This is rather puzzling and, as we will see later, it will be very difficult to interpret an exchange rate shock. However, we could not leave this variable out just because its behaviour is unexpected: the correlation appearing in Table 6 (-0.230) warrants its inclusion. Also, it is worth noting that Kuszczak and Murray's (1987) VAR model exhibits a similar effect of Canadian prices on the exchange rate (see their Tables 11 and 12). We thus proceeded with the analysis despite this counterintuitive result, keeping in mind that it may be part of some overlooked stylized fact that could help explain the puzzles underneath current Canadian macroeconomic relationships.

The disturbance to the short-term interest rate equation will be interpreted as a monetary policy innovation since the only significant variable in the equation suggests a contemporaneous reaction of the interest rate to the monetary base.[28] Price shocks enter this equation with a negative but statistically insignificant coefficient.

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[28] We have deliberately chosen not to incorporate the treasury bill rate (or the Federal funds rate, in the U.S. case) as our interest rate variable in order to be able to capture some of the financial market behaviour. However, the identifying equations for the two interest rates (U.S. and Canadian) behave as monetary authorities reaction functions. The chosen interest rates thus seem to be linked closely to the controlled interest rate variables in both contexts. Ideally, one would incorporate other interest rates to take into account some flavour of the whole interest rate structure but this is, of course, impossible in this kind of small-scale model.

Table 6
Correlation Matrix of the Estimated Canadian Residuals

	BASE	M1	M2-M1	TXCAN	TXCHA	GDPD	GDP
BASE	1.0	-0.167	0.155	0.293	-0.063	0.271	-0.082
M1		1.0	-0.142	-0.369	-0.032	0.004	0.073
M2-M1			1.0	0.296	0.168	0.192	0.091
TXCAN				1.0	0.117	0.132	0.044
TXCHA					1.0	-0.230	-0.032
GDPD						1.0	-0.324
GDP							1.0

Table 7
Contemporaneous Canadian Structural Model

$$\begin{array}{llll}
(1) & \text{BASE} & = & \underset{(0.236)}{0.0715}\,(\text{M2-M1}) + \underset{(0.402)}{0.7839}\,\text{GDPD} + e_{1t} \\
(2) & \text{M1} & = & \underset{(0.239)}{-0.0171}\,(\text{M2-M1}) - \underset{(0.265)}{0.8050}\,\text{TXCAN} + e_{2t} \\
(3) & (\text{M2-M1}) & = & \underset{(0.197)}{0.3595}\,\text{TXCAN} - \underset{(0.691)}{0.5294}\,\text{GDPD} + e_{3t} \\
(4) & \text{TXCAN} & = & \underset{(0.059)}{0.1256}\,\text{BASE} - \underset{(0.257)}{0.0377}\,\text{GDPD} + e_{4t} \\
(5) & \text{TXCHA} & = & \underset{(0.160)}{0.2496}\,(\text{M2-M1}) + \underset{(0.185)}{0.1465}\,\text{TXCAN} - \underset{(0.273)}{0.6436}\,\text{GDPD} + e_{5t} \\
(6) & \text{GDPD} & = & \underset{(0.040)}{0.0323}\,\text{M1} + \underset{(0.190)}{0.2633}\,(\text{M2-M1}) - \underset{(0.076)}{0.2334}\,\text{GDP} + e_{6t} \\
(7) & \text{GDP} & = & e_{7t}
\end{array}$$

Note: Standard errors are given in parentheses.

With a little arm- (or mind) twisting, the equations for the two components of M2 can be associated with money-demand equations. Innovations in (M2-M1) are positively related to interest rate innovations, not an uncommon effect in a money-demand equation in which one does not control for the own rate of interest. The negative (but not significant) effect of price innovations is more difficult to rationalize. The demand-for-M1 equation is incomplete, but leads to a more straightforward interpretation. M1 innovations are negatively related to interest rate innovations and to the non-M1 component of M2 suggesting, in this last case, a form of substitution between the two components. Finally, the equation of the innovations in the monetary base seems to reflect both an institutional factor (lagged reserve accounting) through the positive effect of the innovations in (M2-M1) and a (demand-related) positive adjustment of the base to price innovations.

Let us now proceed to the foreign block. Table 8 shows the reduced-form correlations. As in the previous case, these correlations were used to specify a contemporaneous structure for the estimated residuals. The resulting model is presented in Table 9. Innovations in the real prices of commodities (oil and commodities excluding oil) can be seen as two exogenous international supply shocks, even though the real price of commodities (excluding oil) is related to the price of oil.

The disturbance in the interest rate equation can be identified as a U.S. monetary policy disturbance since the equation appears as a reaction function. The interest rate responds positively to a positive innovation in real output, the GNP price deflator and the real price of commodities.

The innovation in the GNP price deflator reacts negatively to production shocks and positively to shocks to the real price of commodities. However, neither of the effects is statistically significant. The effect of the interest rate innovation in the real income equation is not significant either.

Table 8
Correlation Matrix of the Estimated Foreign Residuals

	GNP	GNPD	TXUS	RPOIL	RPCOM
GNP	1.0	-0.10078	0.33035	-0.47E-01	0.59E-01
GNPD	-	1.0	0.11395	-0.19E-01	0.62E-01
TXUS	-	-	1.0	-0.83E-01	0.24024
RPOIL	-	-	-	1.0	0.19752
RPCOM	-	-	-	-	1.0

Table 9
Contemporaneous Foreign Structural Model

$$\text{(8)}\quad \text{GNP82} = \underset{(0.301)}{0.1523}\ \text{TXUS} + e_{8t}$$

$$\text{(9)}\quad \text{GNPD} = \underset{(0.060)}{-0.0571}\ \text{GNP82} + \underset{(0.038)}{0.0216}\ \text{RPCOM} + e_{9t}$$

$$\text{(10)}\quad \text{TXUS} = \underset{(0.778)}{0.1807}\ \text{GNP82} + \underset{(0.490)}{0.5626}\ \text{GNPD} + \underset{(0.144)}{0.2738}\ \text{RPCOM} + e_{10t}$$

$$\text{(11)}\quad \text{RPOIL} = e_{11t}$$

$$\text{(12)}\quad \text{RPCOM} = \underset{(0.014)}{0.0236}\ \text{RPOIL} + e_{12t}$$

Note: Standard errors are given in parentheses.

It is thus difficult to interpret precisely the disturbances to U.S. prices and real income as demand or supply shocks. But since the impulse response exercise will be performed mainly in terms of Canadian variables, the precise identification of these U.S. shocks is not crucial.

4.3 Impulse response and variance decomposition analysis

4.3.1 Impulse response

Using the above two models, the contemporaneous effects of the U.S. variables on Canadian series and the BVAR dynamic interactions, we derived the impulse responses of all the Canadian variables to a shock to each of the variables. The impulse responses are presented in Figures 3.1 and 3.2.

Some of the comments that we have made on the impulses generated without the identifying restrictions are still relevant:

- For instance, it is still true that most of the shocks to the Canadian variables show little persistence. The interest rate shock is especially short-lived. The only exceptions are the shocks to the exchange rate and to real GDP. Shocks to foreign variables are still very persistent (except for the interest rate shock).
- Even though they react strongly to foreign influences, Canadian monetary aggregates are relatively isolated from the rest of the Canadian system. Although the interactions between Canadian shocks and other Canadian variables are relatively weak, they are stronger than in the previous analysis.
- Compared to the shocks originating within the Canadian economy, foreign shocks all have a much stronger influence on Canadian variables.

We now risk a detailed structural or causal analysis of the results depicted in Figures 3.1 and 3.2.

- A BASE shock (first column of Figure 3.1) does not have much influence on the system, including the monetary subsector: M1 and M2-M1 show slight positive responses. The more persistent effects are also very weak and bear mainly on the exchange rate (slight depreciation) and real GDP which undergoes a surprising contraction. Using U.S. macro time series, Bernanke (1986) also gets the same negative response of real GNP following a BASE shock, even after estimating two different structural models.

- An M1 shock also has a very weak impact on all the variables. Its positive influence on production and prices casts some doubt on the demand origin of this shock which could be much better explained as a multiplier disturbance. M2 has the negative effect on real GDP expected from a money-demand shock. As in Sims' model of the U.S. economy (1986, p. 13), a money-demand disturbance leads to a contraction of income and a rise in prices.

- The interest rate shock has been identified as a possible monetary policy shock. It is noteworthy that its impact on the different variables is generally as expected though not very persistent. It causes a fall in M1 (and the monetary base) and an increase in (M2-M1), possibly through the ensuing increase in rates on bank deposits and substitution away from M1. It has the expected negative effect on real income. The effect on the GDP price deflator is, however, indistinct. The only puzzling effect of an interest rate increase appears in the depreciation that seems to ensue. This effect is surely difficult to explain and, at this stage, we can only invoke the possible existence of some complicated expectations reaction on the part of economic agents.

- The consequences of an exchange rate shock are similar to those observed in the previous exercise. We have not been able to pinpoint the exact structural source of such a shock and its dynamic interrelations with the other variables. The puzzling negative fall in real income associated with an exchange rate shock must thus be accounted for by some fortuitous temporal co-movements.

- A Canadian real price shock can be traced back to a demand origin. It thus raises real GDP. The negative impact on M2 components comes from the estimated negative coefficient of the GDPD variable in the structural equation for M2-M1. Finally, the resulting appreciation of the Canadian dollar is also the direct consequence of the structural coefficient estimated and its persistence is generated from the random-walk property of the exchange rate.

- A real GDP shock leads to a price level reduction and a slight depreciation. Overall, this Canadian supply shock does not have much influence.

Foreign shocks generally lend themselves much more readily to interpretation.

- A U.S. real income shock causes a small increase in U.S. prices and interest rates and is followed by a persistent upward movement in Canadian real GDP. Canadian prices, the exchange rate and interest rates do not show much reaction. All three Canadian monetary aggregates tend to increase, probably reacting to the strong and persistent GDP increase. In the same manner, Canadian variables move parallel to U.S. variables following a U.S. price shock.

- A U.S. price shock leads to a decline in U.S. real income. The same effect was also detected by Sims (1986). This U.S. scenario can also be found in the corresponding Canadian variables with a small increase in GDPD and a slight fall in real GDP. The overall impact on the monetary aggregates is positive. M2-M1 and the monetary BASE reactions are particularly persistent.

- The shock to the U.S. interest rate can be interpreted as a U.S. monetary policy shock. An increase in the interest rate triggers a decrease in U.S. real GNP and a slight rise in the U.S. price level. The drop in U.S. real income in turn is transmitted to its Canadian counterpart, M1 and the monetary BASE. The Canadian interest rate follows the U.S. rate. The Canadian implicit GDP price deflator and M2-M1 show slight positive responses: the M2-M1 result could be attributed to the interest rate increase.

- According to the reduced-form coefficients, the price-of-oil shock led to theoretically perverse responses. These puzzling results have now disappeared: the oil price shock has the expected positive impact on prices and a negative one on real income - in both countries. The two interest rates go up and the Canadian exchange rate increases over time. M1 falls quite strongly, reacting to the interest rate rise and the fall in real income. M2-M1 increases, an effect noted before when the interest rate moves upward.

- Finally, a commodity price shock closely resembles an oil price shock, except for the reaction of M1, which is now positive. It seems that we show here the basic reduced-form relationship estimated by our BVAR.

To sum up, we would like to emphasize the weak and generally short-lived responses caused by Canadian shocks. As well, the impact of some disturbances is surprising (reaction of real income to an exchange rate shock and the effect of a price shock on the exchange rate) and cannot lead to a structural interpretation. As explained earlier, we are reluctant to drop the troublesome effects since they are quite stubborn and show up in the BVAR reduced-form and structural-disturbances coefficients. Further work is clearly needed to clarify these puzzling results. Foreign shocks generally lend themselves much more readily to interpretative nuances and stand out quite noticeably, underscoring their importance in any analysis of the Canadian economy.

4.3.2 Variance decomposition

Table 10 presents the variance decomposition for the Canadian variables on an eight-quarter horizon, which is representative of the results we get at other horizons. Briefly (see Sims, 1980; and Doan and Litterman, 1984, for detailed explanations of the variance decomposition technique), this decomposition provides a kind of ranking of the relative importance of variable j concerning the forecast uncertainty of variable i under study. Given the estimated BVAR coefficients, the estimated contemporaneous effects of the foreign variables, the structural-disturbance coefficients, we have derived the $G_{ij,\ell}$ coefficients (see Figures 3.1 and 3.2) which give the impact after ℓ periods of a one-standard-error structural shock of variable j on variable i. The weight of variable j in the decomposition of variable i after s periods is given by

$$\text{Weights}_{ij}(S) = \frac{\sum_{\ell=1}^{S} G_{ij,\ell}}{\sum_{j=1}^{k} \sum_{\ell=1}^{S} G_{ij,\ell}} . \qquad (20)$$

Table 10
Variance Decomposition

	BASE	M1	M2-M1	TXCAN	TXCHA	GDPD	GDP	NGDP
Canada								
BASE	58.2	1.6	4.6	1.1	0.1	0.6	0.6	0.1
M1	5.8	53.0	3.7	1.9	0.1	5.9	2.1	10.1
M2-M1	1.2	0.6	37.5	0.8	0.4	8.5	0.8	2.1
TXCAN	1.7	10.8	2.9	12.4	1.4	0.3	3.4	3.9
TXCHA	0.6	0.6	0.4	0.3	89.5	0.0	2.2	1.9
GDPD	2.3	0.9	1.2	0.2	7.3	18.8	0.1	10.6
GDP	0.3	0.4	0.3	0.1	1.1	4.7	58.5	39.2
United States								
GNP	0.4	0.5	1.5	0.3	0.0	1.2	3.5	1.3
GNPD	14.0	0.0	18.2	6.1	0.0	19.3	0.1	8.5
TXUS	0.6	23.0	6.0	66.0	0.0	3.8	25.3	14.0
World								
RPOIL	0.5	7.7	0.2	5.6	0.1	0.2	0.7	0.9
RPCOM	15.0	0.7	23.2	5.1	0.0	36.8	2.5	7.3

Note: Each column corresponds to a variable i; each line gives the relative importance of variable j in explaining the forecast errors variance of variable i. The percentage total of each column is 100.

A detailed analysis of this table will shed some light on the indicator studies conducted at the Bank of Canada. For instance:

- The variance of the monetary base is mostly accounted for by its own shocks. M1 is the only Canadian variable that stands out, a result probably linked to the reserve mechanism. The other noticeable shocks are those coming from the U.S. price and from the real price of commodities excluding oil: this can be explained in terms of indirect effects transmitted through the balance of payments or international reserves.

- M1 variance is also dominated by its own shocks. The other noteworthy effects are from Canadian and U.S. interest rates and can easily be explained by theory. The own shocks account for 37.5 per cent of the variance of M2-M1 and the remaining portion is shared by many variables. The monetary base, M1 and interest rate effects were as expected. The large contribution of U.S. and commodities prices must come from indirect channels. It is interesting to note that the Canadian variable that accounts for the largest proportion of the variance of M1 is the interest rate, while the monetary base has the same ranking for M2-M1. These results suggest that the technique used to control these two aggregates might differ.

- The cointegration vector suggested in the estimation stands out clearly in the Canadian interest rate results. U.S. interest rates explain two-thirds of the variance of their Canadian equivalent. The rest of the variance can be traced to the own-shock effects.

- The near random-walk properties of the exchange rate are vividly illustrated by the large proportion (90 per cent) of its variance exclusively explained by its own past shocks. Canadian price shocks rank second. This last effect was certainly behind the perverse effects detected in the impulse responses charts.

- The variance of Canadian prices is explained by numerous factors. First in the list are the commodities price shocks (RPCOM = 36.8 per cent) and the U.S. implicit price deflator (GNPD = 19.8 per cent). We then find the two monetary aggregate components of M2: M1 (5.9 per cent) and M2-M1 (8.5 per cent), an outcome that confirms, in a broader framework, the indicator results of the studies conducted at the Bank. Under the exchange rate regime in place since 1970, a significant proportion of the variance of Canadian prices is thus caused by commodities prices and imported U.S. inflation. Domestic money has a role but the magnitude of its influence is fairly narrow.

- The variance of the Canadian real GDP variable is also mostly related to its own shocks. The other important variable that stands out is the U.S. interest rate - at least in the short term. Of the two monetary aggregates, M1 has a larger contribution but, comparatively, its influence in percentage terms is minimal. Again, this result confirms and puts the conclusions of the indicator studies in perspective.
- Finally, the variance decomposition of Canadian nominal GDP points to various sources: excluding the own effects (GDP=39.2 per cent and GDPD=10.6 per cent), the most important variables are the U.S. interest rate (14 per cent), M1 (10.1 per cent), U.S. prices (8.5 per cent), and commodities prices (7.3 per cent).

It is interesting to note that our results are much in line with the conclusions of the indicator studies conducted at the Bank of Canada. For example, the variance of Canadian prices can be explained by the two monetary components (mostly M2-M1). M1 innovations explain some of the variance of real GDP but have a larger influence on nominal GDP, while M2-M1 plays a minor role in these two cases.[29] Monetary aggregates must thus play an important role in the conduct of monetary policy and the control of M2 appears to be especially important if we aim at price stability in Canada.

Our results also indicate that the monetary variables reveal only a small part of the information necessary to explain the goal variables. This conclusion seems to provide some support for conducting monetary policy according to the checklist approach. However, this contention is somewhat weakened by the strong influence exerted by the foreign variables in the explanation of policy objectives. Therefore, we could attribute the small impact of the monetary aggregates to the overwhelming importance of the exchange rate in the conduct of monetary policy in Canada.

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[29] It is somewhat reassuring to note that our results do not seem to challenge the neutrality of money. Indeed, monetary aggregates affect real GDP only slightly as compared to their effects on the nominal variables of the system.

5. A Forecasting Exercise Over the 1988-89 Period

To assess its forecasting potential in a real *ex ante* context, our BVAR model has been estimated up to the fourth quarter of 1987. We have tried as much as possible to mimic the conduct of monetary policy. For instance, we have adopted nominal GDP as an intermediate target and have computed one- and two-quarter-ahead forecasts of this variable to conform with the publication delays necessary to access all the lagged variables (usually 60 days after the end of a quarter). Note that we have not exploited the contemporaneous information contained in the monetary and financial variables that are available more rapidly. Presumably, the resulting forecast would have been much more accurate.[30]

Table 11 presents the RMSE statistics. The BVAR forecasts compare well with those obtained by AR(4) models or an unconstrained VAR system estimated with the same variables.[31] The one- and two-quarter-ahead RMSE statistics for Canadian nominal GDP are only slightly higher than those of the AR(4) model. However, they are much lower than the standard errors estimated over the whole sample period (1.18 per cent). The BVAR model also performs very well for U.S. nominal income, and is even better than the AR specification for this short period.

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[30] For the time being, the incompatibility between the RATS version on the mainframe computer and the microcomputer version that we use has prevented us from performing the complete forecasting exercise. We intend to perform the exercise as soon as the RATS 3.0 program version becomes available on the mainframe.

[31] We have, in fact, estimated the BVAR model with excessively loose priors on the hyperparameters leading *de facto* to an absence of *a priori* information (see footnote 20).

Table 11
Forecasting Performance 1988:01-1989:04

	NGDP		GDP	
	1	2	1	2
AR	0.45	0.91	0.32	0.70
BVAR	0.56	0.92	0.28	0.39
VAR	1.86	2.81	0.86	1.46

Note: The forecasting performance is measured by the RMSE statistics (horizon: one and two quarters).

The comparison with the unconstrained VAR model clearly reveals the usefulness of the *a priori* information for forecasting. For the two variables considered over the two horizons, the BVAR RMSEs are three times lower than those of the VAR.

6. Conclusions

The primary goal of this project was to build a parsimonious yet effective forecasting model of the goal variables used in the formulation of Canadian monetary policy. The model was also expected to uncover the indicator properties of some macro variables. For reasons identified in the text above, we chose to perform this exercise with a BVAR model. This method allows us to deal with the lack of accuracy of economic theories on the short-term interrelationship among variables. Within a limited sample period, it brings together in a quite flexible manner a relatively large set of dynamic interrelationships.

The exercise did not involve a simple transposition of the BVAR models already estimated for another country. We took great care to tailor the methodology to the problem at hand. For example, we incorporated cointegration priors - a feature not yet exploited to our knowledge. We also devised a practical procedure to implement the impulse-response exercise in the presence of exogenous variables. The resulting procedure is an operational one that allows us to solve significant problems in a parsimonious manner.

These methodological refinements permitted the estimation of a Canadian macro model that includes seven domestic variables and five foreign ones. We thus obtained a much larger model than those described in the U.S. literature to date. The open nature of the Canadian economy did not leave us much choice.

The estimated coefficients were used to compute forecasts both within and without the sample period. Overall, the forecasting performance of the BVAR model is excellent and compares favourably to forecasts obtained with univariate autoregressive structures: for the 1980s, we get much sharper forecasts than those produced by AR models. This is especially true for nominal income and the implicit price index. These results are encouraging since the first variable is used as an intermediate target while the other is the ultimate objective of monetary policy.

The improved forecasting performance of the BVAR model not only reflects accuracy of the dynamic interrelations that are captured by the model (univariate AR models do not forecast as well) but also the *a priori* information used (the unconstrained VAR model had an extremely poor forecasting performance). The dynamic properties of the model were also investigated with an emphasis on the identification of the contemporaneous structure of the disturbances. In most cases, the interrelationships can be interpreted quite easily: the links between monetary variables, the impact of the Canadian interest rate on all variables and the influence of foreign variables. Other responses are more troublesome and do not fit any single theory: i.e., the negative impact of prices on M2-M1, and a drop in real income following a depreciation of the dollar. However, these effects were stubborn enough in the estimation that it was impossible to reject them in the light of recent puzzling economic developments. Obviously, further work is required if we want to solve these puzzles.

The variance decomposition results clearly put the bivariate and multivariate indicator studies conducted at the Bank of Canada in a broader perspective. The forecasting properties of the monetary aggregates uncovered in these studies could be explained by the exclusion restrictions implicitly imposed when only a small set of variables is investigated. Our study confirms that the monetary aggregates are the most important variables to consider when forecasting prices or nominal income. This role, however, is relatively weak when compared to the influence of the foreign variables - at least during the sample period. By excluding the foreign variables, the indicator studies can be misleading since they spuriously enhance the role of the monetary aggregates.

One could find in our study some support for the checklist approach currently used by the Bank of Canada and other central banks in the conduct of monetary policy. However, our results also indicate that the variables included in the checklist must be chosen cautiously.

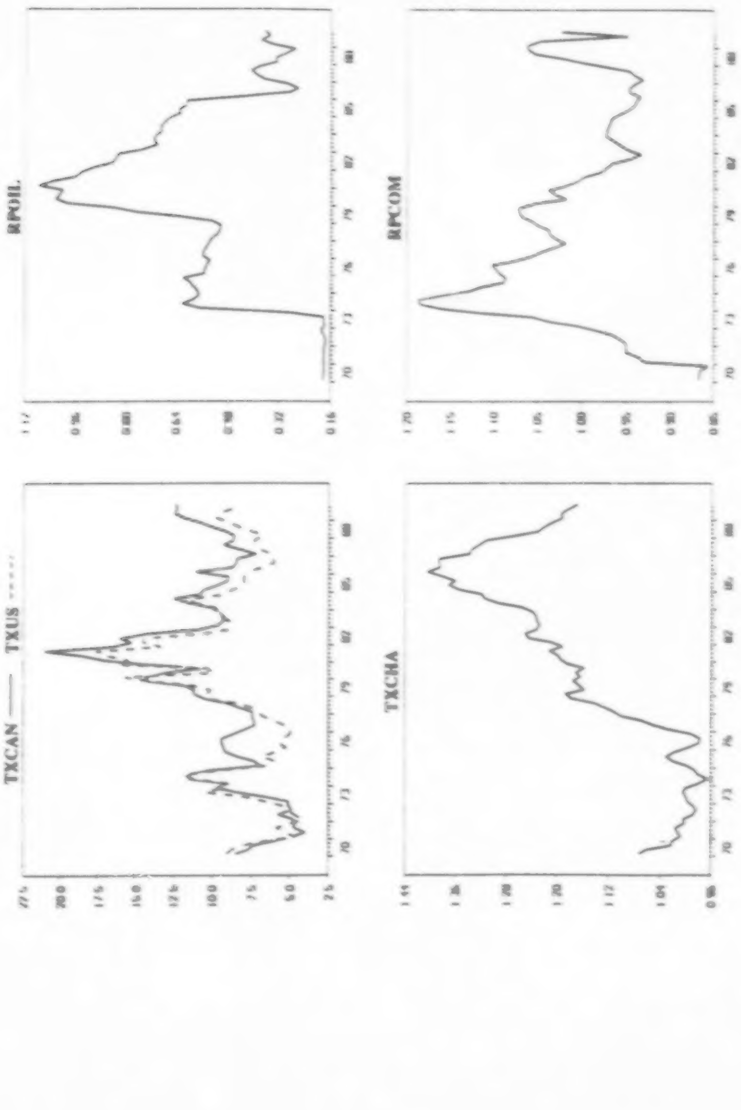
Our model is only a first step towards the creation of such a carefully constructed list. Many possible directions are now open after this first attempt to implement the BVAR methodology in a Canadian context. In the near future, we will be able to compute forecasts using all available information, including observations on current-quarter monetary aggregates and financial variables with the objective of improving our RMSE statistics.

In addition, we could respecify the model without breaking nominal spending into real income and prices. We would thus be able to evaluate the impact of the decomposition currently used in the forecasting performance of this variable. It would also be interesting to introduce a credit aggregate instead of the monetary base.

Other cointegrating priors as well as undisputed long-term stylized facts could also be useful additions. We could exploit the block-exogeneity structure of our approach by replacing our U.S. equations with Sims' (1989) model of the U.S. economy. We would thus have two models working side by side with one taking into account the spillover created by the other.

Appendix Figures

Figure 1: Variables of the System



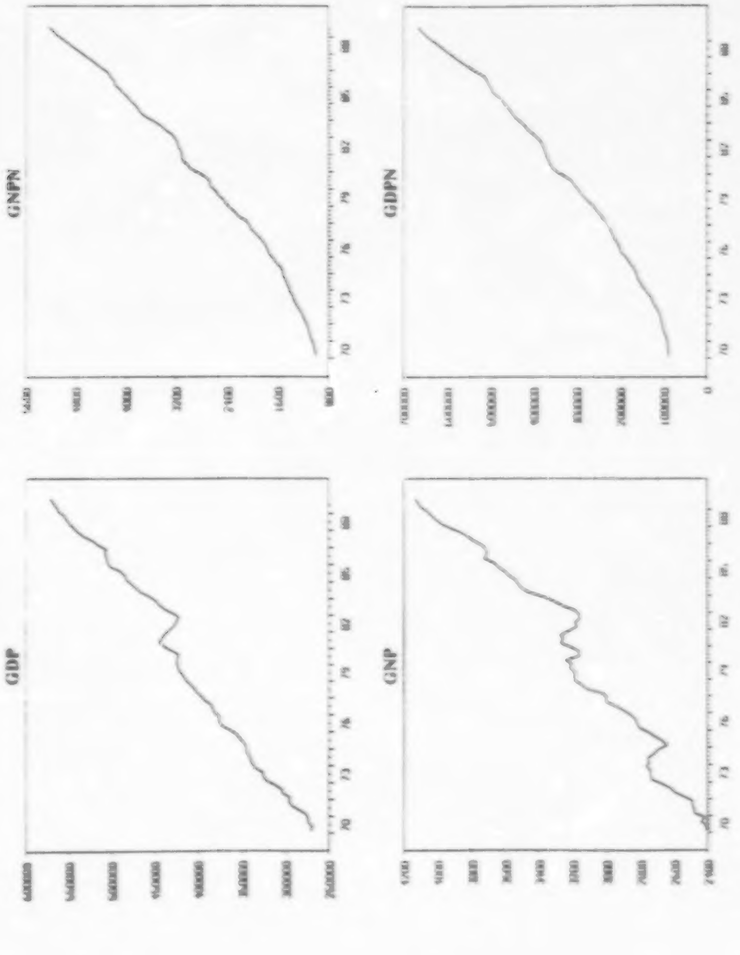


Figure 1: Variables of the System (cont'd)

Figure 1: Variables of the System (cont'd)

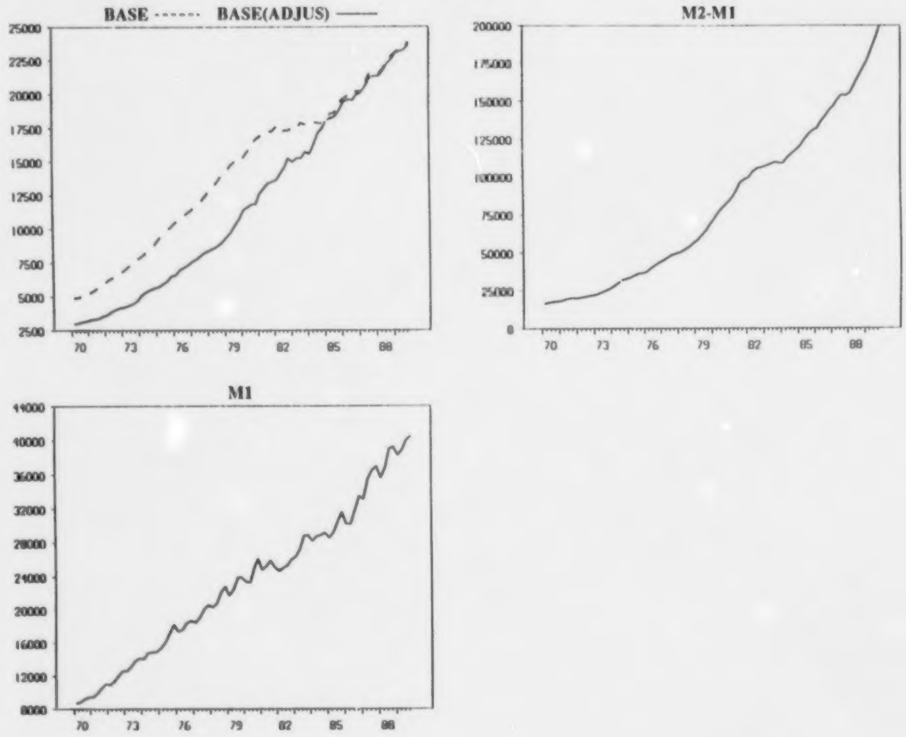


Figure 1 (cont'd)

Variables of the System

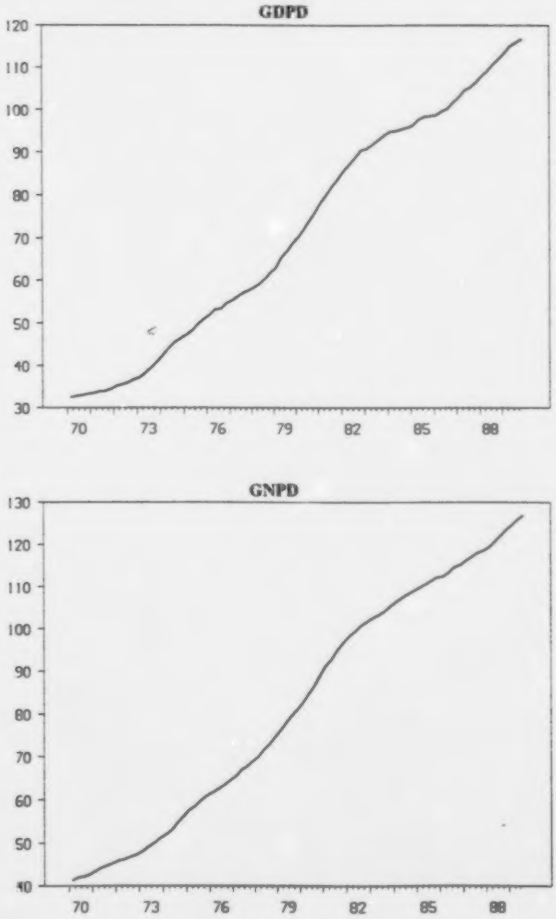


Figure 2.1: Impact of Canadian Shocks (u_t) (All vertical scales must be multiplied by 10^{-2}.)

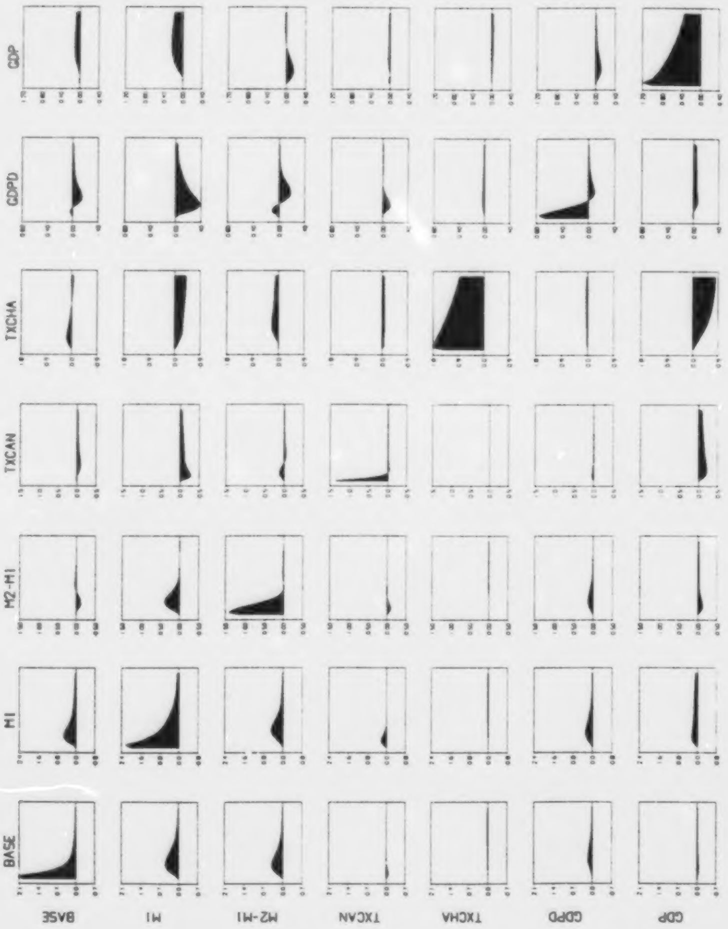
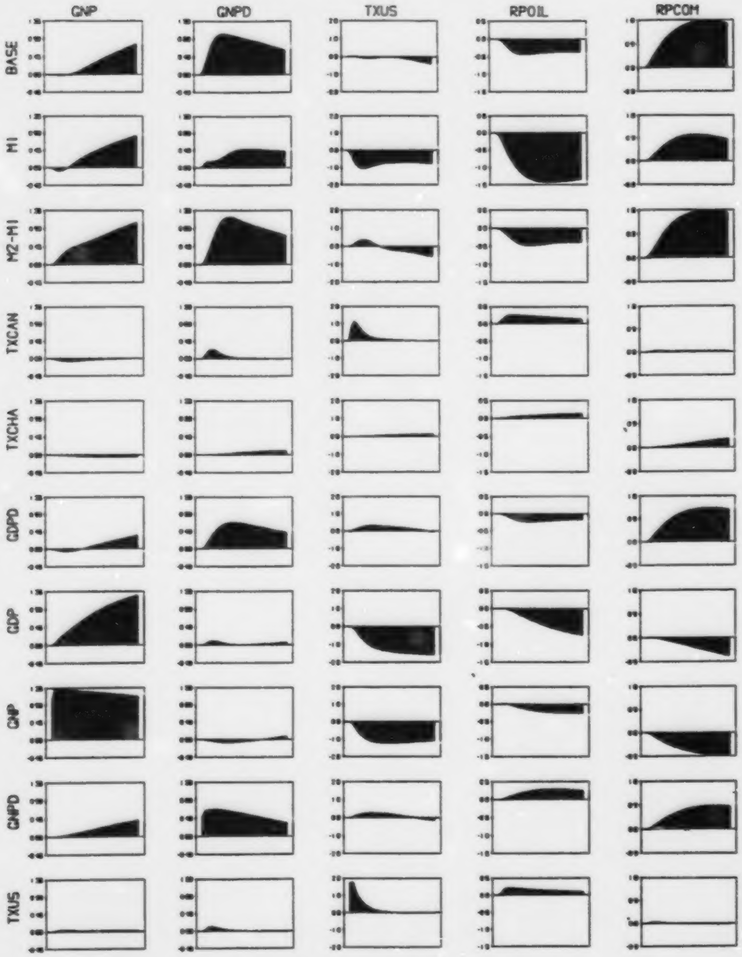


Figure 2.2

Impact of U.S. Shocks (u_t)



Note: All vertical scales must be multiplied by 10^{-2}.

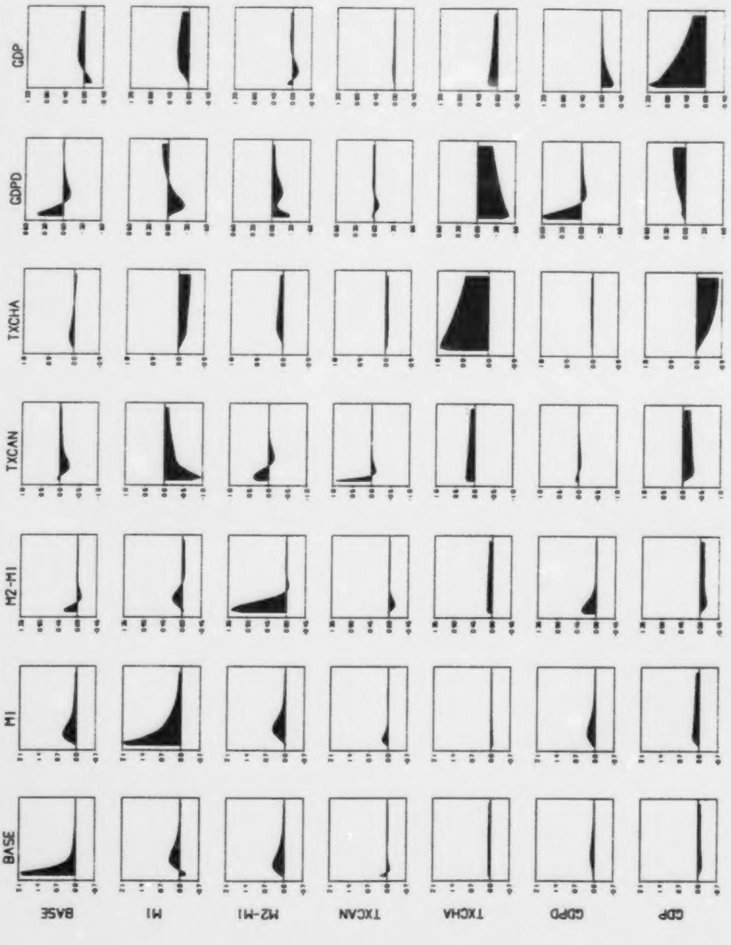
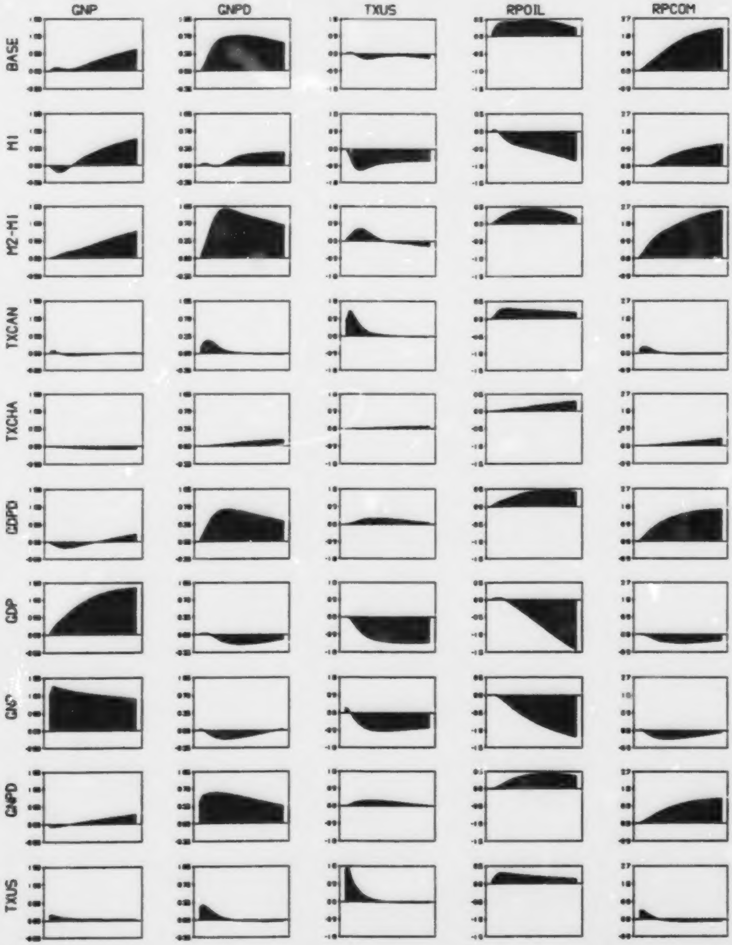


Figure 3.1: Impact of Canadian Structural Shocks (e_t) (All vertical scales must be multiplied by 10^{-2}.)

Figure 3.2

Impact of U.S. Structural Shocks (e_t)



Note: All vertical scales must be multiplied by 10^{-2}.

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Commentary

by Paul Boothe

Introduction

Many of the participants here may not realize that they have just had a kind of rare religious experience. I don't mean that pejoratively - i.e., in the sense that one must have faith to believe the results just presented - all econometric work involves an element of faith. Rather, I mean that the paper belongs to one of the branches of econometric "religion" (in the words of Rick Harris) that we do not see too often. To explain further, I will divide econometric modelling into three so-called "religions":

- **Traditional modelling**

  This approach is taught almost everywhere by many advocates. Taking a structural theoretical model, one derives and estimates reduced-form equations - including only the dynamics found explicitly in the theoretical structural model.

- **AD modelling**

  Centred at Oxford with David Hendry as high priest, this approach involves taking a structural theoretical model, deriving reduced-form equations and long-run restrictions based on theory. The equations are estimated with unrestricted dynamics tested for the long-run theory-based restrictions.

- **BVAR modelling**

  This approach was founded in Minnesota by Christopher Sims and his student, Robert Litterman. Here, one starts without a structural model. Equations with flexible dynamics are estimated for all variables as functions of all others (usually). Parameters are allowed to vary over time. Restrictions based on prior beliefs are used. These restrictions are, however, more flexible in nature than the standard zero restrictions used in the other two approaches. As we will see later on, the current paper is based on a new, much-changed version of this religion.

Comparing "religions"

Given that these methodologies will be used for forecasting *and* for policy analysis, what are the advantages and drawbacks of each?

- **Traditional models**

  The traditional approach seems to be the worst for forecasting and not too good for policy analysis. To be used for forecasting, models of this type usually need to be adjusted or "temped" as it is called at the Bank. This may, in part, be related to dynamic misspecification. The temping procedure is unpopular because it is too subjective, and not easy to replicate. The empirical evidence, although scanty, is that even with these adjustments, the models cannot generate more accurate forecasts than BVAR models.

  Traditional models are easier to use for policy analysis (*if* they are correctly specified) because exogenous and endogenous variables are linked through economic theory. However, these models *are* subject to the Lucas critique in the sense that the reduced-form parameters are usually not "deep," and will change when policy changes substantially.

- **AD models**

  AD models sometimes perform better as forecasting models than traditional models, although this is not always the case. If the true dynamics are simple, or if both models are misspecified, the AD model may suffer from "over-parameterization" - trying to fit every wiggle in the data with the large number of parameters at one's disposal. In an example of AD model forecasting, Debra Glassman and I compared alternative forecasting models for the Canadian dollar in our 1987 paper for the *International Journal of Forecasting*. Using monthly data for 1976-83, we compared a random-walk model (RW), a traditional model and an AD model based on the monetary model of the exchange rate. We found that at the one-month horizon, the RMSE ranking was: RW (1.45 per cent), AD (1.52 per cent) and traditional (10.44 per cent). At the 12-month horizon, the ranking was the same: RW (4.07 per cent), AD (7.23 per cent) and traditional (12.46 per cent). It would be interesting to compare these forecasts with Racette and Raynauld's BVAR exchange rate forecasts. Unfortunately, the sample periods are different.

AD models also have theoretical stories to explain policy, at least in the long run. The short-run dynamics are not based on theory and may be difficult to explain. These models are also subject to the Lucas critique since the parameters are not usually "deep."

- **BVAR models**

One claim that adherents to this religion make is that BVAR forecasts are at least as accurate as those of traditional models, and they do not require the subjective "temping" that goes on here at the Bank and elsewhere. The evidence for this claim comes from Litterman and is based on forecasts of U.S. macro data. From Racette and Raynauld we know that BVAR forecasts are superior to AR(4) forecasts - although this is not always the case (e.g., the exchange rate). Unfortunately, we do not have any traditional or AD model forecasts to compare.

BVAR models do not have the theoretical background to explain the effects of policy changes. The parameters, which are generally allowed to vary through time, are clearly not "deep" and although Sims and Litterman have done some work to try and recover the structural parameters, I think it is fair to say that many in the profession (including one of the high priests) are not yet convinced that this is possible.

Summary

In general, I think the authors have done an excellent job applying a very demanding technique to this forecasting problem. As you will see from my technical comments below, despite the claims occasionally made about earlier types of BVAR analysis, this kind of work is neither simple to replicate nor inexpensive to develop and run. Fortunately, improved forecasts are of very great value to the Bank and so the demanding nature of this methodology should not be viewed as a barrier by Bank economists. However, in my opinion, we do not yet have a very convincing demonstration of its forecasting superiority. To show that a model with more (time-varying) parameters can (usually) beat an AR(4) forecast is not enough. I would find it much more convincing if the authors could show that their BVAR approach dominated traditional simultaneous simulation models used at the Bank and the single-equation AD models referred to above. The Bank could easily provide past RDXF forecasts to make these comparisons possible.

Finally, I am much less sympathetic with the authors' attempts to extract the "structural shocks." To me, this is an attempt to get something for nothing - i.e., theory-based rationalizations should not be attached *ex post* to what are essentially *atheoretic* models. In any case, as Sims states regarding a very similar model, "The problem of generating convenient identification schemes for the nonlinear, non-normal model laid out in this paper appears quite difficult."[1]

A few technical comments

It is important to realize that this paper does not employ the BVAR technique that is normally associated with the economic forecasts produced by the Federal Reserve Bank of Minneapolis. In those models, after choices are made regarding the prior beliefs, the coefficients on the "explanatory" variables in each equation are estimated. However, in this version of the methodology, it is the prior beliefs (hyperparameters) themselves that are estimated. As Sims puts it:

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[1] C. Sims, "*A Nine-Variable Probabilistic Macroeconomic Forecasting Model.*" Discussion Paper 14, Institute for Empirical Economics, Federal Reserve Bank of Minneapolis, 1989, p. 21.

> A classically oriented statistician can ignore the Bayesian jargon in the model description, treat the [coefficients on the explanatory variables] and the [equation errors] as unobserved random disturbances, and interpret the [hyperparameters] as the model parameters. From this perspective, our estimation procedure is simply maximum likelihood. (Sims, 1989.)[2]

Of course, "simply maximum likelihood" is a bit of an understatement since the estimation itself is very demanding (as anyone who has attempted nonlinear maximum-likelihood estimation knows). Thus, the claim made for the relative simplicity of the earlier version of BVAR estimation is not relevant here.

In a related point, BVAR analysts sometimes make the claim that, given the lack of agreement among theorists, they are unwilling to impose theoretical structures to identify their models. However, it is clear that in this exercise the authors, in estimating only the hyperparameters, are themselves imposing a lot of structure (albeit of a different kind) on the model. This is not necessarily inappropriate, but one should remember that the forecasts generated are thus conditional upon this structure in the same way as the forecasts of traditional models.

Finally, again related to structure, traditional modellers sometimes use sensitivity analysis to investigate the robustness of their specifications to changes in structure. This is one way of dealing with situations where theorists do not agree. I believe that BVAR models are sometimes very sensitive to changes in structure. It would be reassuring to know that the authors have performed some sensitivity analysis to test the robustness of their specification.

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[2] C. Sims, "*A Nine-Variable Probabilistic Macroeconomic Forecasting Model.*" Discussion Paper 14, Institute for Empirical Economics, Federal Reserve Bank of Minneapolis, 1989, p. 13.

Commentary

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by Jack Selody

This paper sets out to answer a question of great importance to the conduct of monetary policy - namely, whether monetary aggregates are useful in predicting spending and prices. Accurate predictability is necessary if monetary aggregates are to be useful as intermediate targets or as guides to monetary policy.

Racette and Raynauld address the question of predictability by constructing a Bayesian vector-autoregressive (BVAR) model of the Canadian economy. BVARs are the latest development in the "measurement without theory" school of econometric analysis. BVARs are useful in situations where economic theory is deficient, where the number of economic variables is large, and where the sample period is short. Thus, implicit in Racette and Raynauld's choice of methodology is the view that current macroeconomic models are not theoretically valid and/or the structure of the economy is in a state of flux. Consistent with this view, Racette and Raynauld use a sample that starts in 1970, implying that Canadian economic experience before 1970 is not germane to what happened in the 1970s and 1980s.

The authors judge the predictive power of their BVAR model by comparing it to other models of the same school, namely autoregressive (AR) and vector-autoregressive (VAR) models. The BVAR is judged superior on the grounds that it systematically provides more accurate one- and two-step-ahead predictions for nominal and real GDP. In addition, the BVAR has fewer "perverse" predictions - that is, fewer predictions that are not in accord with established economic theory or conventional wisdom. The superior predictive power of the BVAR reflects the over-parameterization of the AR and VAR models used in the comparison.

Important to the conduct of monetary policy is the finding that money is not the only variable that "explains" fluctuations in spending and prices. With the BVAR, monetary aggregates explain only 12.2 per cent of the variation in spending and 14.4 per cent of the variation of the GDP deflator. Other variables explain 38.0 per cent of the variation in spending and 66.9 per cent of the variation in the GDP deflator.

The finding that other variables besides money are important in explaining fluctuations in prices is not new. Nevertheless, it is an important result in that it suggests that targeting money by itself will not ensure the desired outcome for inflation.

Racette and Raynauld accomplish what they set out to do, i.e., test the relative predictive performance of BVARs. Yet the paper leaves an important question unanswered - namely, whether the predictions of BVARs are robust to changes in economic conditions. This question is particularly important given that the BVARs do not reconcile themselves easily with economic theory or with conventional wisdom. It is also a question that must be answered before BVARs can be used reliably in the conduct of monetary policy. The bottom line here is that economists should not be willing to trust predictions that fly in the face of economic theory.

Racette and Raynauld's BVAR appears to be at odds with economic theory in a number of respects. The paper itself points out "perverse" impulse response functions that, at a minimum, need further investigation. For example, the model predicts that an increase in M2 and M1 will result in a decrease in prices. Is this prediction wrong? If the prediction is right, what are the implications for conventional economic thinking?

BVARs do not reconcile easily with economic theory because they do not lend themselves readily to differentiation between competing hypotheses. For example, innovations in GDP are found to be very persistent. Yet, one does not know whether this persistence is a sign of crowding out, or whether it indicates that supply shocks have been more prevalent than demand shocks through the 1970s and 1980s. The answer to this question is important to the conduct of monetary policy.

Similar questions of interpretation surround the findings that the effect of money on prices is transitory, and that U.S. shocks are more important than Canadian shocks in explaining fluctuations in prices. These results are consistent with monetary control being ineffective in managing inflation and with monetary control being effective but aimed at maintaining Canadian inflation near the U.S. level. Again, differentiating between these hypotheses is critically important to the conduct of monetary policy.

Predictive ability is not the only criterion on which to judge the usefulness of a model for policy analysis. It is equally important that a model "explain" what is going on. Take the example where 58.5 per cent of innovations in real GDP and 89.5 per cent of the innovations in the exchange rate are classified as "own" innovations. The model gives no explanation of what causes these innovations. Real GDP and the exchange rate are seen as being largely unpredictable, but this does not mean that they move in isolation from other economic variables. In other words, predicting how a variable will move is not the same as explaining why a variable ends up where it does.

Finally, the paper contains a number of loose ends. The BVAR used here excludes fiscal policy variables. One would expect that the relationship between money, spending and prices would depend on the stance of fiscal policy. Similarly, wages are excluded from the model. The speed with which money influences prices likely depends on the behaviour and rigidity of wages.

Moreover, it is difficult to assess the importance of such excluded influences because the model does not have economic structure.

In conclusion, Racette and Raynauld have done a good job in showing that a BVAR can perform better than AR or VAR models when monetary aggregates are used to predict spending and prices. This is useful. The relevance of BVAR technology to the conduct of monetary policy remains an open question, however, mostly because the economic structure of BVARs is not explicit or well enough understood.

General Discussion

David Longworth commented that he found this paper very valuable and one of the most successful in describing the "facts" of macroeconomics in Canada in the last 20 years. In contrast to most estimated VAR models that generate counterintuitive results for many shocks, in this model 90 per cent of the results appeared reasonable. He noted that the graphical description of the results was an excellent summary of the paper. He wondered if the sensitivity of the model to U.S. variables reflected that, over the sample period, Canadian economic performance was generally similar to that in the United States. He noted that if Canadian monetary policy aimed at more rapid disinflation than U.S. policy in the future, Canadian and U.S. economic performance might differ more substantially. He suggested that it might be useful to alter one of the "priors" incorporated in their model - by changing the assumption that *nominal* interest parity holds in the long run to one of long-run *real* interest parity.

Paul Boothe disagreed with the view that the merit of the BVAR model should be judged by whether one can give a reasonable structural interpretation to the *ex post* results. The models are designed as *forecasting* tools and their merit relative to structural models is an empirical matter that should be judged by how well they forecast. He added that the complicated links in large structural models may also make it difficult to give their forecasts a structural interpretation and that forecast exercises based on structural models typically incorporate large doses of "judgmental" adjustment to the model-based solution. He was more cautious about using BVAR models for policy simulations but noted that, for this purpose as well, the reliability of the model should be decided empirically.

Steve Poloz suggested that many of the parameters estimated in typical structural models are not "deep" structural parameters and are therefore also subject to the Lucas critique. He liked the fact that VAR and BVAR models are, by construction, free of the simultaneity problem, whereas structural approaches, although conceptually based on ideas of simultaneity, typically take little account of it. Further, he felt that VAR model parameters were relatively free of "data-mining" problems compared to structural models. Raynauld added that proper estimation of structural models required one to begin with microfoundations, such as agent-optimization models, from which deep, structural parameters could be estimated. In this sense, many existing so-called structural models should not be considered to be truly structural.

Poloz argued that VAR or BVAR models and structural models were not in competition: the former were useful for forecasting one or two quarters ahead but were not of much use for longer forecast horizons and for evaluating the effects of different policy environments. He noted that the judgmental adjustment of forecasts of structural-based models referred to by Boothe was aimed principally at altering forecasts of the first few quarters.

Pierre Duguay felt that, even with astructural models, one must be able to place some structural interpretation on the results if those models are to be useful for policy. He noted that in VAR-type models, structure can be imposed in one of two fashions: (i) by imposing constraints on long-run relationships (e.g., as the authors did for nominal interest rate parity) and (ii) by imposing constraints on the covariance matrix of the innovations. He wondered why price homogeneity had not been imposed as a long-run property of the model. He noted that innovations from individual equations in the BVAR will be a combination of demand and supply shocks and that the resulting identification problem might account for one of the authors' counterintuitive results (i.e., when the Canadian dollar appreciates, output increases). He wondered whether it would be possible to give more theoretical appeal and a richer structure to the model by imposing priors on the "slopes" of the demand and supply curves. Raynauld responded that it would be possible to impose price homogeneity on the model, but that he did not think that this would eliminate the counterintuitive impulse response functions pointed out by Duguay and Longworth. Racette added that the purpose of their modelling exercise was to *discover* the dynamic properties and stylized facts characterizing the Canadian economy. If they had imposed the kinds of restrictions that Duguay suggested, the information provided by their model would simply have reflected the priors that they had imposed.

Alain Paquet agreed with Boothe that the authors' BVAR model presented a very useful description of the "stylized facts" of the Canadian economy over the sample period, and argued that several structural interpretations consistent with economic theory could be given to the correlation between the exchange rate and output mentioned by Pierre Duguay.

Charles Freedman remarked that he was struck by the importance of U.S. variables in the model. He wondered if it would be possible to use the model to determine what the required movement in Canadian interest rates would be to offset the effects of a foreign shock on Canadian inflation.

Pierre Fortin mentioned that in this type of VAR analysis, attention was frequently paid to the effects of changes in policy regimes - for example, in Canada the distinction between fixed and flexible exchange rate regimes. He noted that one should be careful in dating regime changes. For example, for long periods in the 1950s and 1960s the Canadian-U.S. exchange rate remained within a narrow band although the exchange rate was not officially fixed. In his own research, he had identified an important change in policy reaction in 1974.

Fortin felt that the authors had perhaps overstated the view that far more restrictions are imposed on typical structural models than on their BVAR model. He noted that their model incorporates many restrictions, although these are of a different nature and often more difficult to interpret than the typical restrictions in structural models. Robert Lafrance asked how the authors decided on the prior constraints that would be imposed on the BVAR. Raynauld replied that the restrictions imposed on their model were minimal and were required given the fairly large number of variables included in the model, the lags required and the span of data available. He commented that they appeared to generate a significant improvement in forecast performance compared to traditional VAR models.

RECONCILIATION

A RECONCILIATION OF THE DYNAMICS OF MONEY-DEMAND AND INDICATOR MODELS

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by Allan Crawford

Introduction

This paper examines empirical money-demand equations and indicator models of spending to discover what they might reveal about the underlying structural dynamics of the Canadian economy. Although both types of models are consistent with certain structural theories, as will be shown here, each exploits different lead-lag relationships between money and economic activity. For example, M2 demand equations for Canada have shown that money growth lags growth in prices and real income. Conversely, bivariate indicator models of spending suggest that money leads prices and real income. In these bivariate models, lagged real M1 adds information to an autoregressive model of real GDP, while lagged M2 adds information to an autoregressive model of prices.

Research has also shown that money maintains its role as a leading indicator of real income and prices when lagged interest rates are added to the bivariate equations. The continued role for lagged money in these multivariate indicator models is somewhat at odds with conventional macro models that suggest the information in lagged money would be captured fully by lagged income and interest rates. Thus, the transmission mechanism underlying the indicator models requires clarification. Similarly, the sources of money-income dynamics in the distributed-lag M2 equation should be investigated, as the Almon lag specification cannot directly identify the underlying mechanisms through which lagged prices and income would affect money demand.

The objectives here are: (i) to provide a structural reconciliation of the finding that money leads GDP in indicator models while GDP leads money in the money-demand equation; and (ii) to explain the principal aspects of the dynamics of the individual models. In this second context, research presented here provides evidence that M2 adjusts less rapidly to real GDP shocks than to shocks in other variables, suggesting that partial adjustment is not the only factor causing lagged real income to affect current money demand. In particular, it would appear that the long-run demand for money depends on both current and lagged real income. Thus, while one focus is to reconcile the timing differences between money-demand and indicator models, the reconciliation should be consistent with different speeds of adjustment of money demand following shocks to real income and prices.

1. Overview

The analysis of these issues starts with an exogenous price level to highlight the roles of the money market and the demand side of the goods market. A theoretical model is presented with permanent income as the scale variable in both the money-demand and spending functions and with partial adjustment of money balances. Agents are assumed to use information on past levels of income when forming their expectations of permanent income. Another important characteristic of the model is a monetary policy reaction function that assumes that the current interest rate is adjusted as contemporaneous money deviates from a desired short-run target. This short-run target is a function of lagged money if the policy objective is to adjust the money stock gradually to a long-run target.

The fixed-price analysis shows that the above theoretical model provides a potential explanation for money as a leading indicator of real income, while prices and real income lead money in the M2 equations. The model's solution for equilibrium real income depends on past income (from the effects of permanent income on consumption), past interest rates (from lagged effects on investment) and lagged money (through the contemporaneous reaction function). Thus, the assumed reaction function can justify the presence of lagged money in indicator models also containing lagged income and interest rates.[1] With respect to money-demand dynamics, this theoretical model demonstrates that the combination of partial adjustment and permanent income can explain why lagged prices and real income affect contemporaneous money demand, with a slower speed of adjustment for shocks to real income.

The empirical validity of the permanent-income/partial-adjustment side of the reconciliation is tested by estimating money-demand equations that model these dynamic mechanisms explicitly. These results are consistent with the Almon lag findings. Virtually all the adjustment of M2 balances to price (and interest rate) shocks is completed within one year as holdings move rapidly to desired levels. In addition, adjustment to changes in real income is less rapid, as money balances do not adjust towards a target dependent solely on current income.

These results suggest two interpretations for the presence of long lags on income in the Almon lag equations. One possibility is that these long lags are proxying the trend component in permanent income. Alternatively, there is some evidence that a portion of transitory income is held in the form of money, which leads to long lags on income in the money-demand equation. Thus, possible causes of the different adjustment speeds for prices and real income in the distributed-lag M2 equation are identified here.

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[1] The model also demonstrates that lagged money contains leading information if it is correlated with any relevant variable omitted from the indicator equation.

In order to study the implications of the supply side of the goods market for the dynamics in indicator models, a variable-price model is considered next. The fixed-price model is initially modified to include both rational expectations and complete wage-price flexibility. Since the lagged money variable in the reaction function can be taken into account by all agents, equilibrium real income is independent of lagged money in this variable-price model. Hence, at least one of the underlying assumptions of rational expectations and full wage-price flexibility must be removed to rationalize the presence of lagged money in indicator models of real output.

The analysis focusses next on a model that maintains the rational expectations assumption but allows non-market clearing with multi-period labour contracts. Since agents negotiating at a given time do not know what the levels of money growth will be over the lifetime of a contract, the price-forecast errors for these contracts will be a function of lagged money. Accordingly, real income is a function of lagged income, lagged interest rates and lagged money. It is concluded, therefore, that lagged money should appear in indicator models of real output if there is a monetary policy reaction function that is dependent on past money growth (and if some labour contracts cannot take into account the full impact of this policy response).

The final section offers some suggestions for future work that would improve our understanding of the dynamics in money-demand and indicator models.

2. Empirical Money-Demand and Indicator Models

This section outlines empirical evidence from the Almon lag demand equation for M2 and indicator models of spending. Later sections provide theoretical explanations for the money-income dynamics in these equations.

2.1 M2 growth-rate equation

A monthly M2 equation developed at the Bank specifies the growth rate of nominal M2 as a function of the growth rates of prices, real GDP, Canada Savings Bonds (CSB), and changes in the own interest rate and substitute rates. The own rate is given by the 90-day interest rate on fixed-term deposits at chartered banks (B90), whereas the 90-day commercial paper rate (R90) represents the rate on competing non-deposit instruments. The impact on M2 from movements in the relative yields on deposits at chartered banks and other financial institutions is measured by the differential between the 90-day rate on fixed-term deposits at banks and the corresponding rate at trust and mortgage loan companies (B90 - T90).

Most studies of money demand contain lagged money, m_{t-1}, as an explanatory variable in order to model the partial short-run adjustment of money balances to desired long-run levels. If m_{t-1} is used in equations in which variables are specified as levels, the estimated adjustment speed is typically found to be implausibly long. Given this apparent shortcoming, the monthly M2 equation defines variables as first differences and models dynamics using Almon lags for explanatory variables. The conventional version of the M2 equation includes current-period values and twelve lags of the growth rates of prices and real GDP, current values and nine lags for the changes in R90 and B90, and current values and sixteen lags for the change in the differential (B90 - T90).[2,3] The lag profiles are assumed to follow a third-order polynomial.

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[2] The final lag has a zero endpoint restriction for all variables except (B90-T90). The sum of the lag coefficients for prices is constrained to equal unity. A dummy variable (CON) is included for the period 1982:07-1984:11 when M2 growth was unusually low.

[3] Only the contemporaneous growth rate for CSB is included since lagged CSB reduces the explanatory power of the M2 equation. Research has shown that CSB has an asymmetric effect on M2 demand during the sales period (traditionally late October and November) and the redemption period (the rest of the year). This asymmetry is modelled with the variable CSB for the redemption period, and separate variables, CSB-Nov and CSB-Dec, for the months (November and December) close to the traditional sales period.

Table 1 shows estimates of the M2 demand equation for the 1970:01-1987:12 period. The standard specification with 12 lags for prices (PGDP) and real GDP (UGDP), shown in the first column, has a long-run real GDP elasticity of 0.432. The interest rate and CSB variables have the expected signs, although CSBs do not have a statistically significant effect on M2 during the redemption period.

In order to study the sensitivity of the results to changes in the specification of prices and real GDP, the lag lengths for these two variables are increased to 15 and 18 months in columns (2) and (3), respectively. The principal effects of raising the lag lengths are higher long-run elasticities for real GDP and lower constant terms,[4] with little change in coefficients for other variables and a slight improvement in explanatory power. The parameter estimates for real GDP and the constant term change by similar amounts as the lag length is increased from 12 to 15 months and then from 15 to 18 months.

The coefficients for the individual lags of real GDP and prices are shown in Table 2 for the models containing 12- and 18-month lags. In the model with 18 lags, the coefficients for prices decrease monotonically, whereas the coefficients for real GDP decrease until t-7, rise from t-8 to t-14, and then fall to zero. It is also worth noting that M2 balances adjust more rapidly to price changes than to real GDP shocks. For the case with 18 lags, 96 per cent of the adjustment to prices is completed within one year, while only 74 per cent of the response to real income occurs within one year.

Table 3 presents estimates of the M2 demand equation when the endpoint in the distributed lag for real GDP is not constrained to equal zero (unlike Table 1). Lengthening the lags for both real GDP and prices gives results similar to those in Table 1. Although there are only marginal improve-

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[4] These trends are partially reversed as the lag lengths are increased beyond 18 months. However, these further increases in lag lengths also worsen the S.E.E. and $\bar{R}^2$.

Table 1
M2 Demand Equation
(1970:01-1987:12)*

	(1)	(2)	(3)
Constant	0.0033 (7.08)	0.0030 (5.84)	0.0027 (4.83)
PGDP	1.0	1.0	1.0
UGDP(12)	0.432 (3.36)		
UGDP(15)		0.510 (3.53)	
UGDP(18)			0.585 (3.65)
R90	-0.009 (1.97)	-0.007 (1.52)	-0.006 (1.39)
B90	0.008 (1.70)	0.006 (1.25)	0.006 (1.17)
B90 - T90	0.031 (2.85)	0.033 (3.03)	0.033 (3.04)
CSB	-0.005 (0.14)	-0.001 (0.04)	0.002 (0.06)
CSB-Nov	-0.143 (15.13)	-0.143 (15.13)	-0.142 (15.00)
CSB-Dec	-0.072 (3.74)	-0.070 (3.68)	-0.069 (3.60)
CON	-0.0029 (3.72)	-0.0028 (3.45)	-0.0026 (3.15)
$\bar{R}^2$	0.704	0.705	0.706
S.E.E.	0.00349	0.00349	0.00348
D.W.	2.05	2.06	2.07

* UGDP has a zero endpoint constraint.

Table 2
Lag Coefficients for Real GDP and Prices
(1970:01-1987:12)

	Real GDP		Prices	
	12 lags (1)	18 lags (2)	12 lags (3)	18 lags (4)
Sum	0.432	0.585	1.0	1.0
t	0.110	0.125	0.100	0.151
t-1	0.082	0.089	0.123	0.135
t-2	0.060	0.061	0.133	0.120
t-3	0.044	0.040	0.134	0.106
t-4	0.033	0.025	0.126	0.093
t-5	0.025	0.015	0.112	0.080
t-6	0.020	0.010	0.094	0.069
t-7	0.016	0.008	0.073	0.058
t-8	0.014	0.009	0.052	0.048
t-9	0.012	0.012	0.032	0.039
t-10	0.010	0.017	0.016	0.031
t-11	0.006	0.021	0.004	0.024
t-12	0.000	0.026	0.000	0.018
t-13		0.029		0.012
t-14		0.030		0.008
t-15		0.029		0.004
t-16		0.024		0.002
t-17		0.014		0.001
t-18		0.000		0.000

Table 3
M2 Demand Equation
(1970:01-1987:12)*

	(1)	(2)	(3)
Constant	0.0032	0.0029	0.0029
	(6.52)	(5.39)	(4.79)
PGDP	1.0	1.0	1.0
UGDP(12)	0.454		
	(3.28)		
UGDP(15)		0.531	
		(3.46)	
UGDP(18)			0.543
			(3.18)
R90	-0.010	-0.007	-0.006
	(2.18)	(1.50)	(1.27)
B90	0.010	0.006	0.005
	(1.78)	(1.24)	(1.05)
B90 - T90	0.012	0.033	0.035
	(1.48)	(3.02)	(3.12)
CSB	-0.002	-0.001	0.001
	(0.06)	(0.03)	(0.02)
CSB-Nov	-0.143	-0.142	-0.143
	(14.50)	(14.93)	(14.92)
CSB-Dec	-0.065	-0.071	-0.070
	(3.31)	(3.69)	(3.64)
CON	-0.0033	-0.0027	-0.0027
	(4.16)	(3.34)	(3.21)
$\bar{R}^2$	0.693	0.704	0.706
S.E.E.	0.00356	0.00349	0.00348
D.W.	2.00	2.07	2.08

* Without endpoint constraints for UGDP.

Table 4
Lag Coefficients for Real GDP and Prices*
(1970:01-1987:12)

	Real GDP		Prices	
	12 lags (1)	18 lags (2)	12 lags (3)	18 lags (4)
Sum	0.454	0.543	1.0	1.0
t	0.111	0.130	0.138	0.152
t-1	0.085	0.089	0.142	0.136
t-2	0.065	0.057	0.140	0.121
t-3	0.049	0.035	0.131	0.106
t-4	0.036	0.019	0.118	0.093
t-5	0.028	0.010	0.101	0.080
t-6	0.021	0.006	0.082	0.069
t-7	0.017	0.006	0.062	0.058
t-8	0.014	0.010	0.043	0.048
t-9	0.012	0.015	0.026	0.039
t-10	0.009	0.021	0.013	0.031
t-11	0.006	0.027	0.003	0.024
t-12	0.002	0.032	0.000	0.018
t-13		0.035		0.012
t-14		0.033		0.008
t-15		0.028		0.004
t-16		0.017		0.002
t-17		-0.001		-
t-18		-0.027		0.000

* **Without endpoint constraints for UGDP.**

ments in $\bar{R}^2$ and S.E.E., raising the maximum lag from 12 to 18 months increases the elasticity of real GDP and lowers the constant term. In contrast to Table 1, most of these changes in parameter estimates occur with the movement from 12 to 15 lags. However, the speeds of adjustment to changes in prices and real GDP are comparable to the results in Table 1. In the model with 18 lags, Table 4 shows that 96 per cent of the eventual adjustment to prices is achieved within one year, while only 78 per cent of the adjustment to real GDP occurs within one year.

In conclusion, this survey of Almon lag money-demand equations does not give a clear preference to the conventional M2 specification that includes 12-month lags for both prices and real income. The explanatory power and S.E.E. of the equation are virtually unaffected as the lag lengths are extended beyond 12 months.

Nonetheless, two useful results emerge from comparisons of the models. First, since the long-run real GDP elasticity increases as the lag length rises above one year, the period of adjustment to real income shocks may be longer than envisioned in the standard M2 equation. Since the constant term decreases as the maximum lag length increases from 12 to 18 months, the constant in the standard equation may, in part, reflect the impact on money demand of real income growth beyond the 12-month lag. Second, in contrast to real GDP, the adjustment of M2 balances to price changes is almost completed within 12 months. Therefore, while partial adjustment might explain the effect of lagged prices on current balances, the fact that the lags on real GDP are significantly longer than for prices suggests that some factor in addition to partial adjustment (and related to lags on real income) affects the dynamics of money demand. Theoretical explanations for the Almon lag results will be examined in Section 3.

2.2 Indicator models of spending

Bivariate indicator models specify the growth rate of real spending or prices as a function of the lagged dependent variable and the contemporaneous and lagged growth rates of money.[5] The optimal lag lengths for explanatory variables are determined sequentially using the Final Prediction Error (FPE) criterion.[6]

Using this methodology, we can determine whether money is a leading indicator of economic activity, but the absence of an explicit structural model of real/financial linkages leaves the sources of the dynamics unclear. After discussing the information content of money, this section concludes with brief comments on whether credit aggregates add information to the monetary models.

2.2.1 Monetary indicator models

The best monetary indicator models for individual components of spending and aggregate GDP are listed in an appendix table.[7] The longest lags for money growth occur in the models for real consumption (current values plus five quarterly lags) and real residential construction (current values plus six lags). In models excluding contemporaneous money, real M1 contains the most information for real consumption, while real M2+ and real M2 are preferred for real business investment and real residential construction, respectively. The broad aggregates, M2 and M2+, are the best leading indicators of the price deflators for consumption and business investment.

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[5] Multivariate models also include other financial market variables such as interest rates, the exchange rate and the TSE price index.

[6] The optimal lag length for the dependent variable is identified before adding a monetary aggregate.

[7] The models for components of spending were estimated for the 1971Q1-1985Q4 sample period. GDP models are discussed in Muller (1989).

Indicator models of GDP show that the most leading information for nominal GDP, real GDP and the price deflator is contained in two lags of M1, real M1 and M2, respectively. An interesting finding is that the same aggregate is not the best leading indicator for both real GDP and prices. Also interesting are the inconsistencies between the indicator models for aggregate GDP and those for individual components of spending. Although the broad aggregates (M2 or M2+) generally contain the most leading information for prices, the superiority of real M1 for real GDP holds only for the consumption component of real spending. The "inconsistencies" are even greater for models of nominal spending. While the narrow aggregate M1 is the best indicator of nominal GDP, the broad aggregate M2+ fulfills this role for two of the three nominal components (including consumption, the largest component of spending).

Finally, the appendix table shows that contemporaneous money contains little information for the price deflators of individual components, whereas it does contribute useful information for real consumption and real business investment.

2.2.2 Multivariate indicator models

The appendix table shows the best indicator models for individual components of spending (as determined by F-tests) when the list of information variables is broadened to include money, credit, the TSE price index, the 90-day commercial paper rate (R90), and the exchange rate.[8] The major change for consumption is that the current-period values and two lags of real total household credit now encompass the information contained in the preferred monetary model for real consumption. Many of the preferred models for business investment and residential construction also contain credit aggregates. In most of these cases, the hypothesis that the sum of the credit coefficients is zero cannot be rejected by a likelihood-ratio test. Thus, both money and credit can act as leading indicators of prices and real spending, although the zero-sum result for credit coefficients suggests that the transmission mechanisms differ for money and credit.

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[8] Muller (1989) discusses the importance of credit as a leading indicator of aggregate GDP.

In this section, it has been shown that income leads money in M2 demand equations while money leads income in indicator models of spending. Several inconsistencies between the indicator models for GDP and the individual categories of spending have also been outlined. In particular, real M1 is the best leading indicator of aggregate real spending, whereas the broader aggregates are better indicators for real investment (real M2+) and real residential construction (real M2). Section 3 considers theoretical explanations for the observed dynamics in the money-demand equation, while Sections 5 and 6 offer explanations for money acting as a leading indicator of current spending.

3. Money-Income Dynamics in Money Demand

In this section, it is shown that the dynamics in the Almon lag M2 equations of Section 2 are consistent with a theoretical model containing *both* permanent income and partial short-run adjustment of money balances. Initially, the separate effect of partial adjustment is isolated by constraining desired money demand to depend on current (not permanent) income.

3.1 Partial adjustment

Equation (1) gives the desired long-run demand for nominal money balances m_t^* as a function of the price level p_t, current real income y_t and the interest rate r_t. Nominal balances are constrained to have a unitary long-run elasticity with respect to prices. With all variables defined as logarithms:

$$m_t^* = p_t + m_1 y_t + m_2 r_t \qquad m_1 > 0,\ m_2 < 0\,. \tag{1}$$

If adjustment costs cause money balances to be adjusted gradually towards their long-run desired levels, the actual quantity of money balances in the current period m_t is a weighted average of the level in the previous period and the current desired level.[9] The parameter δ measures the degree of inertia in adjusting money holdings.

$$m_t = \delta\, m_{t-1} + (1 - \delta)\, m_t^* \qquad 0 < \delta < 1\,. \tag{2}$$

Many empirical studies use equation (2), which models partial adjustment with a lagged dependent variable. The alternative Almon lag approach to modelling short-run money demand may be rationalized by rearranging (2). After repeated substitutions for lagged money, current money balances may be stated as a weighted average of current and past levels of desired holdings, with the weights decreasing geometrically for more distant periods.

$$m_t = \sum_{i=0}^{\infty} \delta^i (1 - \delta)\, m_{t-i}^* \tag{3}$$

where $m_{t-i}^* = p_{t-i} + m_1 y_{t-i} + m_2 r_{t-i}$.

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[9] The short-run money-demand function given by equation (2) can be derived as the optimal solution when changes in money balances are subject to quadratic costs of adjustment.

Equation (3) shows that the current and lagged values of both prices and real income affect contemporaneous money demand if there is partial adjustment of money balances in the short run. From equation (3),

$$\begin{aligned} dm_t / dy_t &= (1 - \delta)\, m_1 \\ dm_t / dy_{t-i} &= \delta^i (1 - \delta)\, m_1 \qquad i = 1, 2, \ldots \end{aligned} \tag{4.1}$$

$$\begin{aligned} dm_t / dp_t &= (1 - \delta) \\ dm_t / dp_{t-i} &= \delta^i (1 - \delta) \qquad i = 1, 2, \ldots \quad . \end{aligned} \tag{4.2}$$

Lag coefficients for all variables decrease monotonically in equation (4) as lag length i increases. Equation (4) also implies that the adjustment speed is identical for shocks to real income and prices. These predictions from a theoretical partial-adjustment model contrast with several properties of the Almon lag M2 equations in Section 2. Specifically, lag coefficients for real GDP do not decrease monotonically in the M2 equation, and money balances adjust more rapidly to shocks in prices than in real output. These characteristics of Almon lag equations can be explained by a theoretical model with both partial adjustment and permanent income in the money-demand equation.

3.2 Permanent Income

A more satisfactory explanation of Almon lag dynamics is obtained by considering the role played by the scale variable in the money-demand equation. If the scale variable is a proxy for desired transactions, and if desired spending is related to permanent income y^P, then y^P should be used instead of current income as a determinant of desired money demand. The implications of permanent income are now examined.

Permanent income is derived using the present value of current and expected future real income. In the infinite-horizon case,

$$y^P_t = r \sum_{s=0}^{\infty} {}_t y_{t+s} \; / \; (1 + r)^s \tag{5}$$

where r is the discount rate and ${}_t y_{t+s}$ is the mathematical expectation at period t of income in period t+s. Some expectations-generating process must be assumed in order to calculate the expectations of future income in equation (5). Consistent with an approach taken in rational expectations/ permanent-income studies of consumption, it is assumed that agents perceive income to be generated by a stochastic autoregressive process of order n+1:

$$y_t = \alpha_1 y_{t-1} + \alpha_2 y_{t-2} + \ldots + \alpha_{n+1} y_{t-n-1} + v_t \, . \tag{6}$$

There is reason to expect that agents would believe that a broader information set than merely lagged y is useful for forecasting future income.[10] For example, indicator models of spending demonstrate that lagged money also contains useful information for predicting the future path of income. The term v_t in equation (6) may be interpreted as including these additional variables as well as a stochastic disturbance.

If income is generated by (6), it is easily shown that rational expectations of future income are functions of current income and n lags of income. Therefore, if agents form rational expectations of future income based on equation (6), permanent income is a function of current and lagged income[11]:

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[10] Consumption studies by Blinder (1981) and Flavin (1981) rely on an autoregressive process to obtain estimates of permanent income. Flavin (1985) uses a bivariate system with income and unemployment to estimate permanent income.

$$y^P_t = y^P(y_t, y_{t-1}, \dots, y_{t-n}) \, . \qquad (7)$$

An important property of equation (7) is that permanent income can be modelled as a function of past income even though permanent income is a forward-looking concept.

If the income-generating equation (6) is a second-order autoregressive process, it can be shown that permanent income is a function of the current and previous period's income, the parameters in the autoregressive equation and the discount rate:

$$y^P_t = r \, \{ \, (1 + r)^2 y_t + \alpha_2 \, (1 + r) \, y_{t-1} \, \} \, / \, w \qquad (8)$$

where $w = (1 + r)(1 + r - \alpha_1) - \alpha_2$.

If we assume partial adjustment of money balances, the short-run demand for money is given by equation (9) when desired long-run demand depends on permanent income as defined in (8):

$$m_t = \sum_{i=0}^{\infty} \delta^i \, (1 - \delta) \, m_{t-i}^* \qquad (9)$$

$$\text{where } m_{t-i}^* = \; p_{t-i} + m_1\{ \, r(1 + r)^2 \, / \, w \, \} y_{t-i} + m_1\{ \, \alpha_2 r(1 + r) \, / \, w \, \} y_{t-i-1} + m_2 \, r_{t-i} \, .$$

---

[11] If agents forecast future income using an indicator model with lagged y and lagged m, the permanent income equation (7) would also depend on lagged money.

In this model with partial adjustment and permanent income, the effects on money balances from the current and previous period's real income, prices and interest rates are:

$$\begin{aligned} dm_t / dy_t &= (1 - \delta)m_1 r (1 + r)^2 / w \\ dm_t / dy_{t-1} &= (1 - \delta)m_1 r (1 + r)(\alpha_2 + \delta(1 + r)) / w \end{aligned} \qquad (10.1)$$

$$\begin{aligned} dm_t / dp_t &= (1 - \delta) \\ dm_t / dp_{t-1} &= \delta(1 - \delta) \end{aligned} \qquad (10.2)$$

$$\begin{aligned} dm_t / dr_t &= (1 - \delta)m_2 \\ dm_t / dr_{t-1} &= \delta(1 - \delta)m_2 . \end{aligned} \qquad (10.3)$$

Equation (10) shows that lagged values of all explanatory variables affect current money demand if adjustment costs cause actual balances to be adjusted gradually towards long-run desired levels. If long-run money demand depends only on current income, the adjustment speed would have the identical value $(1 - \delta)$ for shocks to all the explanatory variables. However, if long-run money demand is a function of permanent income, the adjustment speeds will differ for shocks to prices and real income. This difference in adjustment speeds appears in the estimated Almon lag equations described in Section 2.

4. Empirical Models of Money Demand with Alternative Specifications of Permanent Income

The above analysis indicates that the money-income dynamics in the Almon lag equation are consistent with a theoretical model in which money demand is affected by both permanent income and partial adjustment. This explanation for income leading money in the demand-for-money equation is now tested by estimating M2 equations that model these two channels explicitly.

An important issue in such a test is the selection of a proxy for permanent income. Using the approach outlined in Section 3, a rational expectations measure of permanent income is constructed by assuming income follows a stochastic finite-order autoregressive process. For comparison purposes, money-demand equations estimated with this proxy are compared with results from a simpler specification in which permanent income is calculated as an infinite lag on past income.

4.1 Rational expectations of permanent income

As described in Section 3, if agents believe income follows a stochastic autoregressive process of order n+1

$$y_t = \alpha_1 y_{t-1} + \alpha_2 y_{t-2} + \dots + \alpha_{n+1} y_{t-n-1} + v_t , \qquad (11)$$

then the rational expectation of permanent income is a function of current income and n lags:

$$y^P_t = y^P(y_t, y_{t-1}, \dots , y_{t-n}) . \qquad (12)$$

The approach summarized by equations (11) and (12) is used to obtain a rational expectations proxy for permanent income. Using detrended data for real GDP, the FPE criterion selected the following second-order equation as the optimal autoregressive process over the 1970Q1-1988Q4 period[12] :

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[12] An exponential time trend was used to detrend the real GDP data. Since equation (13) is estimated with detrended data, its parameters are used below to determine movements in permanent income about its trend.

$$y^d_t = \underset{(0.107)}{1.345}\ y^d_{t-1} - \underset{(0.106)}{0.398}\ y^d_{t-2} \tag{13}$$

where y^d_{t-i} $(i = 0,1,2)$ is the deviation of actual income from trend and the figures in parentheses are standard errors. Since the optimal autoregressive equation contains only two lagged deviations, the deviation of permanent income from its trend (y^{pd}_t) is a function of y^d_t and y^d_{t-1} :

$$y^{pd}_t = y^{pd}(y^d_t, y^d_{t-1})\ . \tag{12$'$}$$

If we use the parameter estimates from the autoregressive equation (13), and assume a 3 per cent annual real interest rate and a 20-year time horizon, equation (12′) is evaluated as[13]

$$y^{pd}_t = 0.284\ y^d_t - 0.113\ y^d_{t-1}\ . \tag{14}$$

Total permanent income is proxied by trend income y^T plus the cyclical component defined by equation (14):

$$y^P_t = y^T + y^{pd}_t\ . \tag{15}$$

The permanent-income series calculated from equation (15) is relatively insensitive to changes in current or lagged income. While the quarterly growth rate of real GDP has a standard deviation of 1.02 over the sample period, the corresponding figure for the permanent-income proxy is only 0.276. This pattern is consistent with prior beliefs that permanent income is relatively unresponsive to changes in current conditions.[14] As will be shown below, one consequence of this insensitivity is that current and lagged income have relatively little direct effect on money balances via the permanent-income channel.

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[13] This calculation is made using a finite-horizon version of equation (8) in Section 3.

The above rational expectations measure of permanent income is included in the long-run demand-for-money equation (16):

$$m_t^* = p_t + m_1 T + m_2 y^P_t + m_3 r_t + m_4 CON + m_5 CSB_t \quad (16)$$

where T is a time trend.

If money balances are adjusted gradually towards the long-run desired level m_t^*, the short-run demand for money is

$$\begin{aligned} m_t = \; & \delta m_{t-1} + (1 - \delta)(p_t + m_1 T + m_2 y^P_t + m_3 r_t + m_4 CON) \\ & + m_5 CSB_t - \delta m_5 CSB_{t-1} \qquad (17) \end{aligned}$$

where all variables are defined in logarithmic form.

The Almon lag M2 equation suggests that movements in CSB have only a contemporaneous effect on money balances. This characteristic is imposed in equation (17). The partial-adjustment mechanism in (17) implies that the impact of lagged prices on money demand decreases geometrically with lag length, whereas the lag profile for real income depends on interactions between the partial-adjustment and permanent-income channels. The response of money demand to changes in permanent income, current income and lagged income are given by equations (18.1), (18.2) and (18.3), respectively:

---

[14] Movements in the permanent-income series are dominated by changes in aggregate trend income.

$$dm_t / dy^P_t = (1 - \delta)\, m_2 \qquad (18.1)$$

$$dm_t / dy_t = (1 - \delta)\, m_2\, dy^P_t / dy_t \qquad (18.2)$$

$$dm_t / dy_{t-1} = \delta(dm_t / dy_t) + (1 - \delta)\, m_2\, dy^P_t / dy_{t-1}\, . \qquad (18.3)$$

Equation (17) is estimated with quarterly data for the 1970-88 period. Column (1) of Table 5 shows that all the parameters have the expected signs and are statistically significant (with the exception of R90). As shown by the parameter estimate for rho, it was necessary to include an autocorrelation correction in the equation. The partial-adjustment coefficient ($\delta = 0.492$) implies that approximately 50 per cent of the gap between actual and desired balances is eliminated within one quarter, and that 94.1 per cent of the eventual adjustment to price changes is completed within one year.

The income dynamics estimated from equation (17) suggest a much smaller effect on money demand from current and lagged income than was found in the Almon lag equations. As noted from equation (14), the rational expectations proxy for permanent income increases by only 0.284 times the increase in current income. This low sensitivity is reflected in the income elasticities of money demand defined by equations (18.1) to (18.3). Whereas the parameter estimates in column (1) imply the elasticity (18.1) with respect to current permanent income is 0.287, the elasticity (18.2) for current income is considerably smaller (0.082), and lagged income has a negligible effect on money holdings. Thus, unlike the Almon lag model, past income has a relatively small direct impact on money demand.[15] One explanation for this

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[15] The sum of the elasticities for current income and all lags is 0.088. In contrast, the long-run elasticity for real income lies within the 0.40-0.60 range in alternative versions of the Almon lag equations (see Tables 1 and 3).

Table 5
M2 Equations with Alternative Specifications of Permanent Income (1970Q1-1988Q4)

	(1)	(2)	(3)
Time	0.006	0.007	0.007
	(9.34)	(16.61)	(16.58)
Y^P	0.565	0.566	0.568
	(49.39)	(50.33)	(49.93)
R90	-0.023	-0.035	-0.028
	(1.42)	(2.14)	(1.75)
CON	-0.033	-0.021	-0.027
	(2.49)	(1.61)	(2.03)
CSB	-0.080	-0.083	-0.086
	(3.39)	(3.54)	(3.61)
δ	0.492	0.488	0.524
	(4.57)	(4.40)	(4.77)
β_1		0.105	
		(2.37)	
β_2		0.223	
		(2.83)	
α_m			0.245
			(2.89)
sum-y*	0.088	0.855	0.568
rho**	0.871		
	(13.60)		
$\bar{R}^2$	0.99987	0.99988	0.99988
S.E.E.	0.007322	0.007071	0.007151
D.W.	2.24	2.28	2.24

* sum-y is the sum of the coefficients on current and lagged income.
** rho is the first-order autocorrelation coefficient.

difference is that the lags of income in the Almon equation act as a proxy for the trend component of permanent income.[16]

4.2 Permanent and transitory income

The results in Section 4.1 suggest that current and lagged income have a relatively slight influence on money demand through their *direct* effects on agents' rational expectations of permanent income. However, if individuals hold some portion of transitory income as money balances, there is another channel that may cause income to lead money in demand-for-money equations. Darby (1972) hypothesized that a fraction of current transitory income is stored as temporary cash balances, and that the cumulative stock of these balances is decreased over time as these holdings are converted into durable goods or non-monetary financial assets. This view of money is incorporated into the previous money-demand equation (17) as follows:

$$\begin{aligned} m_t = {} & \delta\, m_{t-1} + (1 - \delta)\, m_t^* + \beta_1\, (y_t - y^P{}_t) + (1 - \beta_2)\, ST \\ & + m_5\, CSB_t - \delta\, m_5\, CSB_{t-1} \end{aligned} \tag{19}$$

$$0 < \beta_1 < 1, \quad 0 < \beta_2 < 1$$

$$\text{where } ST = \sum_{i=0}^{\infty} \beta_1\, (1 - \beta_2)^i\, (y_{t-i} - y^P{}_{t-i})$$

is the beginning-of-period stock of transitory money balances, β_2 is the portion of the beginning-of-period stock that is converted into spending or non-monetary financial assets during period t, $\beta_1(y_t - y^P{}_t)$ is the addition to transitory money balances from current transitory income, and m_t^* is defined by equation (16). An estimating equation is obtained by applying a Koyck transformation to (19):

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[16] In this regard, it is noted that the constant term decreased in the Almon lag equation as the lag length for real income was increased.

$$\begin{aligned} m_t = \; & (1 - \beta_2 + \delta)\, m_{t-1} - \delta(1 - \beta_2)\, m_{t-2} + \beta_1(y_t - y^P_t) + m_5\, CSB_t \\ & - (1 - \beta_2 + \delta)\, m_5\, CSB_{t-1} + \delta(1 - \beta_2)\, m_5\, CSB_{t-2} \\ & + (1 - \delta)\,(m_t^* - (1 - \beta_2)\, m^*_{t-1})\,. \end{aligned} \tag{20}$$

Column (2) of Table 5 gives the parameter estimates of equation (20). The addition of transitory income to the money-demand equation eliminates the autocorrelation problem present in column (1) and improves the explanatory power of the model. The parameter estimate for the dummy variable CON is reduced in magnitude relative to column (1) and becomes statistically insignificant. All other parameters have the anticipated signs and are significant. Most notably, the estimates of β_1 and β_2 indicate that some transitory income is stored as money balances and that the cumulative stock of these balances is used for spending or converted into non-monetary assets at a relatively slow rate. In contrast to equation (17), which excluded the transitory-income channel, equation (20) contains a strong explicit role for lagged income, with the sum of the current and lagged income elasticities equal to 0.855. The adjustment of money balances to changes in real income is slower than in the Almon lag equations, as only 56.2 per cent of the adjustment is completed within one year.[17] However, the parameter estimate of 0.488 for δ implies an adjustment speed for prices (94.3 per cent within one year) that is similar to the value in the Almon lag equations.

In conclusion, the results presented in column (2) of Table 5 indicate that money balances show a greater sensitivity to lagged income than can be attributed to the rational expectations proxy for permanent income. The underlying model suggests that this responsiveness may arise from money acting as a temporary store of transitory income. This mechanism may be one reason for income leading money in the Almon lag equation, and might also explain why money leads spending in indicator models.

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[17] In the Almon lag equation with 18-month lags for prices and real GDP, 74 per cent (96 per cent) of the eventual response to real GDP (price) shocks is completed within one year (see Table 2).

The results in Sections 4.1 and 4.2, using the rational expectations measure of y^p, will now be compared with those from an alternative specification for y^p.

4.3 Infinite-lag modelling of permanent income

Early empirical studies of the role of permanent income in the money-demand function assumed that y^p is determined by a weighted average of current income and permanent income in the previous period[18] :

$$y^p_t = \alpha_m y_t + (1 - \alpha_m) y^p_{t-1} \qquad 0 < \alpha_m < 1 \qquad (21)$$

where α_m is the elasticity of permanent income with respect to current income. After repeated substitutions, permanent income can be expressed as an infinite distributed lag on income:

$$y^p_t = \sum_{i=0}^{\infty} \alpha_m (1 - \alpha_m)^i y_{t-i} \, . \qquad (21')$$

If we assume that the short-run money-demand function is defined by equation (17), and use (21´) as the proxy for permanent income, a Koyck transformation gives the following estimating equation for money demand:

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[18] For example, see Feige (1967). Kohli (1981) applied this proxy for permanent income to Canadian data for the 1955-76 period.

$$\begin{aligned} m_t = {} & (1 - \alpha_m + \delta)\, m_{t-1} - \delta\, (1 - \alpha_m)\, m_{t-2} + m_5\, CSB_t \\ & - (1 - \alpha_m + \delta)\, m_5\, CSB_{t-1} + \delta\, (1 - \alpha_m)\, m_5\, CSB_{t-2} \\ & + (1 - \delta)\, Z \qquad (22) \end{aligned}$$

where $Z = p_t + m_1\, T + \alpha_m\, m_2\, y_t + m_3\, r_t - (1-\alpha_m)\, (p_{t-1} + m_1\, T_{t-1} + m_3\, r_{t-1})$.

It is informative to compare equation (22) with the model in Section 4.2 that included both the rational expectations measure of permanent income as well as transitory-income effects on money balances. From equations (20) and (22), the two models are observed to have similar estimating equations,[19] although the underlying causes of the dynamics are quite different. In equation (22), the money-income dynamics reflect the role of lagged income in the determination of permanent income.[20] In contrast, analysis of the rational expectations model in Sections 4.1 and 4.2 suggested that current and lagged income have a relatively small direct effect on money demand through the permanent-income channel, whereas transitory income has a major impact on money-income dynamics.

Parameter estimates of equation (22) are listed in column (3) of Table 5. As expected, given the similarities between equations (20) and (22), the partial-adjustment coefficient δ has a similar magnitude in the two equations, as can be seen in columns (2) and (3). Moreover, the speeds of adjustment to shocks in real income and prices using the infinite-lag specification of y^p are close to those from the model with the rational expectations measure of y^P and transitory-income effects on money balances.[21]

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[19] Equations (20) and (22) have identical structures for the non-income variables. For example, the variable m_{t-1} in (20) is multiplied by $(1 - \beta_2 + \delta)$ where β_2 is the rate at which the stock of transitory balances is reduced in the current period. In (22), m_{t-1} is multiplied by $(1 - \alpha_m + \delta)$ where α_m is the elasticity of permanent income with respect to current income.

[20] If the adjustment parameter α_m is less than one, permanent income (and therefore desired money demand) is a function of an infinite lag on income. In this case, money balances will adjust at a slower rate to changes in real income than to changes in price.

4.4 Conclusions

In this section, alternative explanations for the slow adjustment of money to income in the Almon lag money-demand equations have been evaluated. The evidence indicates that desired money balances are related to permanent rather than current income, such that the long lags on income in the Almon equations may be proxying the trend component of permanent income. Evidence that transitory income affects money balances was also presented. This relationship would exist if money balances are held to finance transitory consumption or if money acts as a temporary store of wealth. These transitory-income effects are shown to give a slow adjustment of money balances to changes in real income.

Finally, it was shown that a model using an infinite-lag specification of permanent income yields results similar to those from a model with both rational expectations of permanent income and transitory-income effects on money balances. Therefore, an infinite lag of past income may be capturing the combined impact of permanent and transitory income on money demand.

This section has provided empirical evidence that partial adjustment and permanent income may explain why real income and prices lead money in the M2 demand equation. Consideration will now be given to the dynamics in indicator models.

5. Money Leading Income: Price Level Exogenous

As described in Section 2, bivariate and multivariate indicator models show that lagged money growth is a leading indicator of price and real income growth. Since these relationships are estimated by adding money to the optimal autoregressive models, it is necessary to explain why lagged money provides information not already contained in the lagged dependent variables or in lagged interest rates (in the multivariate models). Sections 5 and 6 suggest that a monetary policy reaction function with lagged money as an argument may account for the leading-indicator property of money. In order to highlight some basic characteristics of the reaction function, the analysis of indicator dynamics in this section begins by using the simplifying assumption of a fixed price level. Section 5 also analyzes whether interactions between money and credit creation contribute to the leading information in money.

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[21] The parameter estimates in column (3) of Table 5 imply that 53.9 per cent (92.5 per cent) of the adjustment to real income (prices) is achieved within one year.

5.1 Reaction functions

Consider the following fixed-price model:

$$y_t = c_1 y_{t-1} + c_2 r_t + c_3 r_{t-1} + v_{1t} \tag{23}$$

$$c_1 > 0, c_2 < 0, c_3 < 0 .$$

$$m_t = \delta m_{t-1} + (1 - \delta)(p_t + m_1 y_t + m_2 y_{t-1} + m_3 r_t) + v_{2t} . \tag{24}$$

Equation (23) is the economy's IS curve. The aggregate demand for goods is assumed to be a function of permanent income, the current interest rate and the lagged interest rate. Permanent income is represented in equation (23) with a single lag of real income.[22] Lagged interest rates are included in (23) to model any delays between the financing of investments and the actual date of expenditures. The money-demand equation (24) uses permanent income as the scale variable and assumes there is partial short-run adjustment of money balances to desired levels ($\delta > 0$). The terms v_1 and v_2 are stochastic disturbances in the goods and money-demand equations.

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[22] As noted in Section 3, this is consistent with rational expectations of permanent income if income follows a second-order autoregressive process.

Monetary policy is modelled using an interest rate rule for controlling the money stock. The policy reaction function assumes that the current interest rate is adjusted as contemporaneous money growth gm_t deviates from a short-run target rate gm^*_t :

$$\Delta r_t = \phi\,(gm_t - gm^*_t) + \eta^m_t \qquad \phi > 0\,. \tag{25}$$

If money growth is currently above the short-run target, equation (25) indicates that policy actions place upward pressure on r_t so as to move money growth towards gm^*_t. The term η^m_t is a random variable that includes all other determinants of central bank behaviour and a stochastic disturbance.[23]

The short-run target growth rate, gm^*_t, determined at the start of the period, is consistent with the objective of moving money gradually towards a long-run target growth rate gm^L. If lagged money growth differs from this long-run target, according to equation (26) the central bank seeks to eliminate some fraction of this gap in the present period:

$$gm^*_t = gm^L + \tau\,(gm_{t-1} - gm^L) \qquad 0 < \tau < 1\,. \tag{26}$$

If $\tau \neq 0$, there is policy gradualism with only partial movement in the current period towards the long-run objective.

The policy regime does not allow long-run base drift in growth rates if the long-run target gm^L is exogenous. The implications of base drift in the growth rate are studied by assuming that the central bank adjusts its current long-run target if money growth exceeded the long-run target in the previous period:

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[23] The applicability of (25) is not restricted to policy regimes containing explicit monetary targets. If money growth is simply one of several informal policy guides, both $(gm_t - gm^*_t)$ and the additional terms in η^m_t will influence movements in the interest rate.

$$gm^L_t = gm^L_{t-1} + \epsilon\,(gm_{t-1} - gm^L_{t-1}) \qquad \epsilon > 0. \tag{27}$$

If we use equations (24) to (27), the reaction function with gradualism and base drift is (25′):

$$\begin{aligned}\Delta r_t = \phi\,\{\,&(1-\delta)(gp_t + m_1\,gy_t + m_2\,gy_{t-1} + m_3\,gr_t)\\ &+ (\delta - \tau - (1-\tau)\epsilon)\,gm_{t-1} + v_{2t}\\ &- (1-\tau)(1-\epsilon)\,gm^L_{t-1}\,\} + \eta^m_t\,. \end{aligned} \tag{25′}$$

In the absence of base drift ($\epsilon = 0$), the current interest rate is negatively related to lagged money growth in equation (25′) if the coefficient for lagged balances in the money-demand equation is less than the gradualism policy parameter ($\delta < \tau$). The addition of base drift to the reaction function implies that lagged money is more likely to have a negative effect on the current interest rate.

Equation (25′) reveals that the relationship between r_t and lagged money growth depends on three policy parameters (ϕ, τ and ϵ) when both gradualism and base drift affect the short-run target growth rate. The relationship between current interest rates and lagged money also depends on other characteristics of the reaction function. For example, the preceding analysis was based on reaction function (25), which assumed that the central bank considers only the contemporaneous deviation of money growth from its target when determining desired interest rate adjustments. Alternatively, the central bank could consider a longer time horizon, with a tendency to place stronger upward pressure on interest rates if growth also exceeded its target during periods in the recent past. If we consider the case where the reaction function depends on current and previous-period values of the gap between actual and target money growth:

$$\begin{aligned} \Delta r_t &= \phi_1 (gm_t - gm^*_t) + \phi_2 (gm_{t-1} - gm^*_{t-1}) + \eta^m_t \\ &\quad \phi_1 > 0, \quad \phi_2 > 0 . \end{aligned} \tag{28}$$

If there is no base drift ($\epsilon = 0$), the reaction function implied by equations (24) and (28) contains two lags of money growth:

$$\begin{aligned} \Delta r_t = {} & \phi_1 (1 - \delta)(gp_t + m_1\, gy_t + m_2\, gy_{t-1} + m_3\, gr_t) \\ & + (\phi_1(\delta - \tau) + \phi_2)\, gm_{t-1} - \phi_2 \tau\, gm_{t-2} \\ & - (\phi_1 + \phi_2)\, gm^L + \phi_1 v_{2t} + \eta^m_t . \end{aligned} \tag{29}$$

Thus, when both the current and lagged deviations of money growth from its target enter the reaction function, the first lag of money growth has an ambiguous effect on the current interest rate while the second lag has an unambiguously negative impact on r_t.

5.2 Reaction functions and indicator dynamics

The complete fixed-price model is given by equations (23) and (29) when the reaction function depends on the current and lagged deviations of money growth from its target and there is no base drift. The solution for the growth rate of real income in this model is

$$\begin{aligned} gy_t = {} & k \{ ((1 - \phi_1(1 - \delta)m_3)c_1 + \phi_1(1 - \delta)m_2 c_2)\, gy_{t-1} \\ & + (1 - \phi_1(1 - \delta)m_3)c_3\, gr_{t-1} + (\phi_1(\delta - \tau) + \phi_2)c_2\, gm_{t-1} \\ & - \phi_2 \tau c_2\, gm_{t-2} - (\phi_1 + \phi_2)c_2\, gm^L \\ & + (1 - \phi_1(1 - \delta)m_3)\, v_{1t} + c_2(\phi_1 v_{2t} + \eta^m_t) \\ & + \phi_1(1 - \delta)c_2\, gp_t \} \end{aligned} \tag{30}$$

where $k = 1 / (1 - \phi_1(m_3 + m_1c_2)(1 - \delta)) > 0$.

From equation (30), and recalling $c_2 < 0$, $\phi_1 > 0$, $\phi_2 > 0$, $\tau > 0$, and $\delta > 0$, we obtain equation (31):

$$\begin{array}{llllllllll} gy_t = f(& gy_{t-1}, & gr_{t-1}, & gm_{t-1}, & gm_{t-2}, & gm^L, & v_{1t}, & v_{2t}, & \eta^m_t, & gp_t) \\ & (?) & (-) & (?) & (+) & (+) & (+) & (-) & (-) & (-) \end{array} \qquad (31)$$

where the signs of coefficients are indicated below each determinant of real income growth. The lagged income term, which enters through the permanent-income variables in the spending and money-demand equations, has an ambiguous sign since y^p has a positive effect on both spending and the demand for money.

Equation (31) shows that real income growth depends on lagged income growth, lagged interest rates and two lags of money growth when the reaction function depends on the current and one-period lags of the gap between actual and desired money growth. Thus, the reaction function channel can explain why lagged money would add information in multivariate indicator models that also include lagged values of income and interest rates.[24]

Equation (31) identifies other potential sources of the leading information in lagged money. Since the bivariate indicator models of real GDP exclude gr_{t-1}, these models may attribute some of the information in gr_{t-1} to lagged money growth. Similarly, in both the bivariate and multivariate models, lagged money may convey leading information if it is correlated with other relevant variables excluded from these models (such as the goods-market shock v_{1t}).[25] In addition, if income is measured with error, and lagged money is correlated with true lagged income, lagged money would add information when measured past income is included in the regressions.

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[24] Since lagged money depends on lagged income and interest rates, the additional information in lagged money reflects random shocks to money demand and movements in variables included in the money-demand equation but excluded from the indicator models (such as CSBs).

It is observed from equation (30) that the coefficients for lagged money depend on a variety of policy parameters from the reaction function. Consequently, the parameter estimates for lagged money in indicator models would vary with changes in policy regimes. For example, if the current policy regime involves less gradualism than was the case during most of the sample period used for estimation, current forecasts from the model would tend to overpredict the impact of lagged money on real output.

5.3 Lagged money as an indicator of liquidity constraints

Lagged money may also provide leading information on spending through channels that were not considered in the preceding model. For example, credit had no explicit role in the determination of spending. This assumption is consistent with the pure permanent-income theory of consumption which states that households can reach their optimal levels of consumption by borrowing and lending in perfect capital markets. However, if some households are unable to borrow against expected future income, liquidity (borrowing) constraints would prevent these households from attaining their desired consumption levels.[26] Accordingly, increases in contemporaneous credit may raise current spending by relaxing these liquidity constraints. Thus, if c^*_t is desired consumption and c_t is actual consumption, the difference between desired and actual spending may decrease with an increase in the flow of consumer credit $(h_t - h_{t-1})$:

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[25] This possibility may arise if the goods-market shock v_{1t} is defined to include variables (such as credit) which affect spending but are not explicit arguments in (23). Section 5.3 considers this issue in greater detail.

[26] Using a variety of methodologies and data sets, Flavin (1985), Hayashi (1985), Wilcox (1989), and Zeldes (1989) show that consumption is more responsive to current income than would be predicted by a pure theory of permanent income. These studies present evidence that liquidity constraints may be responsible for the deviations of spending from permanent-income levels. Similarly, Fazzari and Athey (1987) and Whited (1989) conclude that borrowing constraints affect real investment spending by businesses.

$$c^*_t(y^p_t, ...) - c_t = \beta_0 - \beta_1 (h_t - h_{t-1}) . \qquad (32)$$

Equation (23) is now modified to include the flow of consumer credit as a determinant of total spending with a parameter $c_4 > 0$:

$$y_t = c_1 y_{t-1} + c_2 r_t + c_3 r_{t-1} + c_4 (h_t - h_{t-1}) + v_{1t} . \qquad (23')$$

The solution for equilibrium real income growth is now positively related to the current growth rate of credit and negatively related to the lagged growth rate, with (23′) suggesting that the sum of the coefficients for gh_t and gh_{t-1} will equal zero[27] :

$$gy_t = f(gy_{t-1}, gr_{t-1}, gm_{t-1}, gm_{t-2}, gh_t, gh_{t-1}, ...) . \qquad (31')$$

Equation (31′) implies that the growth rate of credit is an omitted variable in indicator models that exclude credit aggregates. If lagged money is correlated with contemporaneous and lagged credit, the parameter estimates for lagged money in these models would reflect both the reaction function and the liquidity channels. A positive correlation between lagged money and contemporaneous credit could arise for several reasons. First, if financial institutions are unable to adjust their loan stocks to long-run desired levels within a single period, the change in the loan stock following an increase in deposits will be distributed over time, giving a positive correlation between lagged money and current credit growth. These dynamic portfolio adjustments may cause lagged money to be negatively related with contemporaneous liquidity constraints and positively related to current spending.

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[27] A complete model would specify the determinants of contemporaneous credit growth.

Recent theories of the credit market provide a second reason why lagged money might proxy contemporaneous credit and liquidity constraints. Bernanke and Gertler (1989) consider a situation where only the borrower can observe without cost the outcome of an investment project. In this asymmetric information case, they show that an increase in the borrower's net worth reduces the agency (monitoring) costs of a loan,[28] leading to an increase in the quantity of credit and real investment spending. Similarly, using the Stiglitz-Weiss (1981) model, Calomiris and Hubbard (1987) show that the initial balance sheet position of a borrower influences the amount of credit rationing. If lagged money is closely correlated with the overall net worth of borrowers, these credit market theories suggest lagged money would be a leading indicator of economic activity.

Table 6 presents empirical evidence on the strength of the liquidity constraint explanation for lagged money appearing in monetary indicator models. If lagged money acts primarily as a proxy for liquidity constraints, the addition of contemporaneous and lagged credit to these monetary models should substantially reduce the quantitative importance of lagged money variables.

In Table 6, this prediction is tested by adding the current growth rates of money and credit aggregates to the original monetary model of real GDP. The inclusion of contemporaneous real M1 (or real M3) raises the explanatory power of the real GDP model (see columns (2) and (3) of

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[28] Agency costs are lowered since the increase in net worth allows the borrower to raise the amount of collateral invested in the project.

Table 6
Indicator Models of Real GDP with Money and Credit*

	Original model	Extended models			
		RM1	RM3	RTCC	RTCC
	(1)	(2)	(3)	(4)	(5)
Constant	0.833	0.793	0.686	0.766	0.827
	(5.94)	(5.74)	(4.62)	(6.17)	(6.90)
UGDP-1	0.037	0.057	-0.014	-0.042	0.030
	(0.34)	(0.53)	(0.13)	(0.41)	(0.32)
RM1-1	0.162	0.130	0.150	0.156	0.179
	(3.16)	(2.48)	(3.02)	(3.43)	(4.07)
RM1-2	0.172	0.163	0.179	0.169	0.179
	(3.22)	(3.13)	(3.46)	(3.71)	(3.92)
RM1-0		0.104			
		(2.14)			
RM3-0			0.174		
			(2.43)		
RTCC-0				0.449	0.394
				(5.52)	(5.25)
RTCC-1				-0.326	-0.394
				(3.84)	
$\bar{R}^2$	0.299	0.332	0.343	0.500	0.488
S.E.E.	0.852	0.831	0.824	0.719	0.728
LLF**	-93.584	-91.210	-90.547	-79.678	-81.120

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* These models were estimated for the period 1970Q1-1988Q4.

** LLF is the value of the log-likelihood function.

Table 6), but a greater increase in explanatory power is achieved (see column (4)) when current and one-period lags of the growth rate of real total consumer credit at banks and non-banks (RTCC) are added to the original model. The parameter estimates for the first and second lags of real M1 decrease only slightly (and remain statistically significant) when RTCC is added to the monetary model. When the sum of the credit coefficients is constrained to equal zero (as suggested by earlier theoretical discussion), the parameters for lagged money (see column (5)) increase slightly relative to the original model in column (1). This zero-sum constraint for credit coefficients is not rejected by a likelihood-ratio test.

In conclusion, the evidence cited above indicates that the leading information in lagged money is *not* related to its ability to proxy credit or liquidity constraints.

5.4 Balance sheet effects on desired spending

Mishkin's (1976) analysis provides a third potential explanation for lagged money acting as a leading indicator of spending. Briefly stated, financial assets provide liquidity thus reducing the probability of having to sell consumer durables (and incur losses in a highly imperfect market) in the event of a decrease in income, whereas liabilities increase this probability. Thus, while the balance sheets of borrowers might affect spending indirectly through credit markets (as in Section 5.3), balance sheet positions may also have direct effects on desired spending. Mishkin provides supporting empirical evidence that the beginning-of-period stock of household assets (liabilities) has a significant positive (negative) impact on real spending on consumer durables in the United States.

Mishkin's work implies that the determinants of desired spending on consumption in equation (32) should be revised to include lagged assets and liabilities of households. If lagged money balances are used to represent household assets, and the interest cost on previously outstanding debt ($r_{t-1}h_{t-1}$) is the liability variable, then

$$c_t = c^*(y^P_t, m_{t-1}, r_{t-1}h_{t-1}) - \beta_0 + \beta_1 (h_t - h_{t-1}) . \qquad (32')$$

Higher money balances reduce the probability of incurring losses from forced sales of consumer durables after a decrease in income, so that m_{t-1} has a positive effect on contemporaneous spending.[29]

Therefore, in addition to the interest rate effects through the reaction function channel, lagged money may contain leading information through its impact on household balance sheets.[30]

6. Variable-Price Models

The previous section used a fixed-price model to explain the presence of lagged money in indicator models of real spending. A policy reaction function was shown to be capable of explaining the leading information in money. In this section, two variable-price models are presented to highlight the implications of aggregate supply conditions for the dynamics in indicator models of prices and real spending.

6.1 Market-clearing models

The first model assumes that complete wage-price flexibility permits the goods and labour markets to clear each period and that agents have rational expectations. The economy is modelled by equation (33):

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[29] The inclusion of debt-servicing costs as a determinant of desired spending on consumer durables, c^*, suggests that the leading information in credit will vary with the level of interest rates in previous periods.

[30] Stochastic simulations of the above structural models using plausible parameter values would be useful for assessing whether these explanations are broadly consistent with the evidence from the estimated indicator models.

$$y_t = c_1 y_{t-1} + c_2 r_t + c_3 r_{t-1} + v_{1t} \tag{33.1}$$

$$m_t = p_t + m_1 y_t + m_2 y_{t-1} + m_3 r_t + v_{2t} \tag{33.2}$$

$$\Delta r_t = \phi (gm_t - gm^*_t) \tag{33.3}$$

$$gm^*_t = gm^L + \tau(gm_{t-1} - gm^L) \tag{33.4}$$

$$n^d_t = n_0 + n_1 (w_t - p_t) \qquad n_1 < 0 \tag{33.5}$$

$$n^s_t = n_2 + n_3 (w_t - {}_{t-1}p_t) \qquad n_3 > 0 \tag{33.6}$$

where ${}_{t-1}p_t$ is the mathematical expectation of p_t given all information available at the end of period t-1, and w is the nominal wage rate. The random disturbances v_{1t} and v_{2t} are assumed to have zero means.

Equations (33.1) and (33.2) repeat the demand-for-goods and the money-demand equations (with $\delta = 0$) from the fixed-price model of Section 5.[31] The reaction function defined by (33.3) and (33.4) assumes there is no long-run base drift. Labour demand n^d is a function of the real wage, while the dependence of labour supply (33.6) on the expected real wage assumes that workers have imperfect short-run information on the current price level.

From equations (33.1) to (33.4), the growth rate of aggregate demand is derived as a function of lagged variables and growth in the current price level.

$$\begin{aligned} gy^d_t = {} & a_1 gy_{t-1} + a_2 gr_{t-1} + a_3 gm_{t-1} + a_4 gm^L \\ & + a_5 gp_t + \epsilon^d_t \end{aligned} \tag{34}$$

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[31] Specifying the IS curve as a function of the real interest rate instead of the nominal rate r_t does not alter the conditions under which the reaction function rationalizes the presence of lagged money in indicator models.

where $a_2 < 0, a_5 < 0$

$$a_3 = - \phi \tau c_2 / (1 - \phi m_3 - \phi m_1 c_2) > 0$$

$$a_4 = - \phi(1 - \tau)c_2 / (1 - \phi m_3 - \phi m_1 c_2) > 0$$

$$\epsilon^d_t = \{ (1 - \phi m_3) v_{1t} + \phi c_2 v_{2t} \} / (1 - \phi m_3 - \phi m_1 c_2) .$$

Lagged money has a positive impact on demand in equation (34) by raising the short-run target gm^*_t in (33.3).

An aggregate output supply schedule is obtained from equations (33.5) and (33.6). If the labour market clears each period with $n^d_t = n^s_t$, equilibrium employment is :

$$n_t = n_4 + n_5 (p_t - {}_{t-1}p_t) \qquad (35)$$

where $n_5 = -n_1 n_3 / (n_3 - n_1) > 0$.

If workers underpredict the current price level, the increase in perceived real wages leads to a shift in labour supply at each nominal wage, and an increase in the equilibrium level of employment, according to equation (35).

The supply of output, determined by the employment equation (35) and a production function, depends on the price-forecast error. Therefore, the growth rate of output supply is a function of unexpected inflation:

$$gy^s_t = b_1 (gp_t - {}_{t-1}gp_t) \qquad (36)$$

where $b_1 = -n_1 n_3 f_n / (n_3 - n_1) > 0$ and f_n is the marginal product of labour.

If the goods market clears each period, the equilibrium growth rate of prices is calculated from equations (34) and (36) as:

$$gp_t = \{ a_1\, gy_{t-1} + a_2\, gr_{t-1} + a_3\, gm_{t-1} + a_4\, gm^L + b_1\, {}_{t-1}gp_t + \epsilon^d_t \} / (b_1 - a_5) . \qquad (37)$$

Equation (37) offers an explanation for lagged money growth providing leading information in the indicator model of prices. Since lagged money growth affects contemporaneous policy actions through the reaction function, gm_{t-1} has a positive effect on prices by raising the contemporaneous demand for goods. In addition, if agents take this policy response into account when they form their expectations of the inflation rate, ${}_{t-1}gp_t$, lagged money has a supply-side effect on prices.

If rational expectations are assumed such that the expected growth in prices is the mathematical expectation of equation (37), the current-price forecast error is independent of money:

$$gp_t - {}_{t-1}gp_t = \epsilon^d_t / (b_1 - a_5) . \qquad (38)$$

The solution for the growth rate of real output is obtained by substituting equation (38) into (36):

$$gy_t = \{ b_1 / (b_1 - a_5) \}\, \epsilon^d_t \qquad (39)$$

where (as defined in equation (36)) b_1 depends on the elasticities of labour supply and labour demand.

Equation (39) indicates that growth in contemporaneous real output depends solely on the current random disturbance ϵ^d_t. Real output is independent of lagged money since rational agents take into account the policy reaction function (33.3) when forecasting prices. In conclusion, the reaction function can explain why money is a leading indicator of prices, but it does not justify a role for lagged money in indicator models of real output under conditions of rational expectations and complete wage-price flexibility.[32] The consequences of removing the latter assumption are considered next.

6.2 Multi-period labour contracts

The assumption that wage adjustments achieve continuous market-clearing ignores the reality of long-term contracts that result in short-run rigidity in nominal wages.[33] Another shortcoming of the above model, as shown by (39), is that the output effect from forecast errors will be weak if the real wage elasticity of labour supply (n_3) is low. Empirical evidence suggests that in fact the elasticity of labour supply is not strong enough to account for significant variations in output.[34] The continuous market-clearing assumption in the model is also inconsistent with the coexistence of involuntary unemployment and unfilled job vacancies.

These comments suggest that money-income dynamics should be examined in a model with long-term labour contracts and demand-determined employment in at least some sectors. Consider a model in which labour contracts specify nominal wages for two periods. If we assume that an equal number of firms renegotiate each period, one-half of all firms currently pay a wage rate set at the end of period t-1, while the remainder pay a wage determined at the end of t-2. Given price expectations for each period of the

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32. The fixed-price analysis of Section 5 showed that lagged money would also contain leading information if it is correlated with omitted variables. As concluded for the reaction function, omitted variables cannot account for money leading real output with rational expectations and complete wage-price flexibility, since real output growth in (39) is a function of only the random (zero mean) contemporaneous disturbance.

33. Imperfect wage flexibility is particularly important for the present analysis, given its focus on the short-run dynamics in quarterly indicator models.

34. Pencavel's (1986) survey of empirical studies reports elasticities of labour supply within the range -0.15 to 0.15.

contract, nominal wage rates are set to maintain a target level z for the expected real wage. The nominal wages paid in period t are

$$ {}_{t-1}w_t = z + {}_{t-1}p_t \tag{40.1} $$

$$ {}_{t-2}w_t = z + {}_{t-2}p_t \tag{40.2} $$

where ${}_{t-i}w_t$ is the current nominal wage in contracts negotiated at the end of t-i, z is the target real wage, and ${}_{t-i}\,p_t$ is the expected price level for period t conditional on information available at the end of t-i. There will be a wage differential between the two sets of firms if price expectations for period t change between t-2 and t-1.

If employment by each firm is determined by its labour-demand schedule, total employment equals aggregate labour demand.[35] With two-period labour contracts, the original labour-demand schedule (33.5) is modified to reflect the assumption that an equal number of firms renegotiate the nominal wage each period.

$$ \begin{aligned} n_t &= n^d_t \\ &= n_0 + n_1\, 0.5 \sum_{i=1}^{2} ({}_{t-i}w_t - p_t)\,. \end{aligned} \tag{41} $$

By substituting equation (40) into (41), we obtain

$$ n_t = n_0 + n_1\, z - 0.5 n_1\, (p_t - {}_{t-1}p_t + p_t - {}_{t-2}p_t)\,. \tag{42} $$

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[35] The following discussion could be modified to allow both supply- and demand-determined employment in different sectors.

Since one-half of all firms currently pay a nominal wage determined at the end of t-1 and the rest pay a wage set at the end of t-2, aggregate employment depends on price expectations from both t-1 and t-2.

The growth rate of the aggregate supply of output implied by equation (42) is

$$gy^s_t = 0.5\, b_1\, (gp_t - {}_{t-1}gp_t + gp_t - {}_{t-2}gp_t) \qquad (43)$$

where $b_1 = -\, n_1\, f_n > 0$ with demand-determined employment.

The impact of lagged money on real output is determined by solving for the price-forecast errors in the output-supply equation. If the goods market clears, the growth rate of prices is determined by equations (34) and (43):

$$\begin{aligned} gp_t = {} & (\, a_1\, gy_{t-1} + a_2\, gr_{t-1} + a_3\, gm_{t-1} + a_4\, gm^L \\ & + 0.5b_1\, ({}_{t-1}gp_t + {}_{t-2}gp_t) + \epsilon^d_t\,) \,/\, (b_1 - a_5)\,. \end{aligned} \qquad (44)$$

The forecast errors with rational expectations are determined from (44):

$$gp_t - {}_{t-1}gp_t = \epsilon^d_t \,/\, (b_1 - a_5) \qquad (45.1)$$

$$\begin{aligned} gp_t - {}_{t-2}gp_t = {} & \{\, a_1\, (gy_{t-1} - {}_{t-2}gy_{t-1}) + a_2 (gr_{t-1} - {}_{t-2}gr_{t-1}) \\ & + a_3\, (gm_{t-1} - {}_{t-2}gm_{t-1}) + 0.5b_1\, ({}_{t-1}gp_t - {}_{t-2}gp_t) \\ & + \epsilon^d_t\, \} \,/\, (b_1 - a_5) \end{aligned} \qquad (45.2)$$

where $a_3 = -\, \phi\, \tau\, c_2 \,/\, (1 - \phi m_3 - \phi m_1 c_2) > 0$.

The forecast error (45.1) depends only on the contemporaneous random disturbance ϵ^d_t for those contracts negotiated at the end of period t-1. However, if the monetary policy reaction function involves gradual adjustment ($\tau > 0$) to a long-run growth rate so that a_3 is positive, the forecast error (45.2) for contracts set at the end of period t-2 will also depend on the lagged growth rate of money. Since the random shocks to money in period t-1 could not be predicted at the end of t-2, the contemporaneous policy response to lagged money will affect the price-forecast errors for all contracts negotiated before t-1.

The growth rate of real output, obtained by substituting equation (45) into (43), is a function of lagged money growth when there are multi-period labour contracts[36]:

$$gy_t = f(gy_{t-1}, gr_{t-1}, gm_{t-1}, \epsilon^d_t) . \tag{46}$$

The preceding analysis shows that imperfect short-run wage flexibility combined with a reaction function with gradualism can explain why lagged money gives leading information in indicator models of prices and real output. The analysis also identifies several supply-side factors that might introduce parameter instability into the estimated indicator models. If the average length of labour contracts decreases, the average nominal wage rate becomes more responsive in the short run to recent changes in money, and lagged money may provide less leading information for real spending. Similarly, the discussion has pointed out that the leading information in money will vary depending on the price-expectations process. Lagged money growth would be a stronger leading indicator of real output if agents use a simple adaptive expectations rule than if they form rational expectations from the correct structural model.

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[36] More precisely, the forecast errors depend on the unanticipated component of money with rational expectations, whereas the indicator models use data for actual money growth. Thus, actual data for money growth has information content if it is correlated with unanticipated money growth.

The fixed-price analysis in Section 5 showed that parameter instability will also occur if there are changes in the policy parameters in the central bank's reaction function. These shifts in policy regimes also have important supply-side implications. If agents do not immediately perceive the change in policy behaviour, there will be a learning period during which price-forecast errors for all agents would depend on lagged money. Therefore, the relationship between lagged money, prices and real output could vary substantially over time.

7. Conclusions

This paper has examined theoretical explanations for the lags of prices and income in empirical money-demand equations and the lags of money in indicator models of prices and income. It has been shown that a theoretical money-demand equation combining partial adjustment and permanent income can explain the differences in the lags on prices and real income in the demand for M2.

The presence of lagged money in indicator models can arise as a consequence of an interest rate rule for controlling the money stock. Here, we have assumed a reaction function in which the current interest rate is adjusted as money growth deviates from a desired short-run target.[37] The current interest rate setting will depend on lagged money if policy attempts to move money growth gradually to a long-run target growth rate. In a model with rational expectations, lagged money is shown to have leading information for prices and real spending if multi-period labour contracts prevent some nominal wage rates from immediately taking into account the policy actions implied by the reaction function.

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[37] The leading-indicator role for money is not restricted to a regime with formal monetary targets. Past money has information content even if it is simply one of several variables used as informal guides to policy.

As outlined in the preceding section, the theoretical model suggests that changes in policy regimes would alter the relationship over time between lagged money and contemporaneous prices and real income. These shifts would introduce parameter instability into the estimated indicator models. This result suggests that caution is necessary when using these models for forecasting purposes. If policy behaviour were to be significantly different from most of the sample period used to estimate the indicator models, forecasts might give unreliable information about future economic activity. (However, the paper presented by Muller at this conference shows that over the estimation period used in the Bank's indicator models, this has not been a statistically significant problem.)

Two other potential explanations for the leading information in lagged money were also briefly outlined here. The theoretical analysis suggests that past money growth will be a leading indicator if it is correlated with omitted variables in the indicator equations. One application of this result is the hypothesis that lagged money acts as a proxy for liquidity constraints on spending. This possibility is suggested by recent theories of credit markets in which borrower net worth is an important determinant of net credit flows. If this channel is important, we would expect that adding credit to the original monetary indicator models would substantially reduce the parameter estimates for lagged money. However, the addition of contemporaneous and lagged consumer credit to the indicator model of real GDP leads to a large increase in explanatory power without any decrease in the size or statistical significance of the lagged money variables. Therefore, although money and credit creation are interrelated, the leading information in lagged money does not arise from its ability to proxy credit or borrowing constraints.

Mishkin's (1976) study of the impact of the household balance sheet on consumption suggests a third channel through which lagged money might contain leading information on current spending. Through its effects on liquidity, an increase in lagged household assets (including money) can increase the optimal level of consumer expenditures on durables.

Our understanding of the dynamics in money-demand and indicator models would be strengthened by further research in several directions. One area would be to integrate key results from indicator models into the analysis of the effects of permanent income on money demand. In particular, modelling the rational expectation of permanent income using an autoregressive process ignores the leading information contained in lagged money.

Finally, evidence was cited that money and credit growth contain independent information about spending growth. In contrast to money growth, however, the sum of the coefficients on credit growth is insignificantly different from zero in the indicator model of real GDP growth, suggesting that it is the acceleration in credit growth that contains important information.[38] The zero-sum result is consistent with a model in which liquidity constraints on the level of consumption are relaxed by an increase in the contemporaneous flow of consumer credit. The role of credit as an indicator is a topic worthy of further study.

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[38] See Freedman and Longworth (1990) for further discussion of this result.

Appendix

Table A:1
Indicator Models[1]

	Monetary models		Best models[2]	
		$\bar{R}^2$		$\bar{R}^2$
Consumption				
Nominal	(I) M2+(0)	0.223		
	(X) M2+(1)	0.195		
Real	(I) RM1(5)	0.393	(I) RTHC(2)	0.381
	(X) RM1(5)	0.242	(X) RM1(5),TSE(5)	0.351
Price	(I) M2(2)	0.737		
	(X) M2(2)	0.742		
Business investment				
Nominal	(I) M2+(1)	0.347	(I) M2+(1),BLACB(3)*	0.456
	(X) M2+(1)	0.341	(X) M2+(1),SCB(2)*	0.400
Real	(I) M2+(0)	0.206	(I) M2+(0),BLACB(3), TSE(4), R90(6),PFX(6)	0.565
	(X) RM2+(2)	0.224	(X) SCB(2)*,TSE(1), R90(6),PFX(3)	0.354
Price	(I) M2+(1)	0.569	(I) STBC(1),TSE(0)	0.639
	(X) M2+(1)	0.574		
Residential construction				
Nominal	(I) M1(2)	0.461		
	(X) M1(2)	0.401		
Real	(I) RM1(6)	0.401	(I) RMC(5)*,RM1(6)	0.518
	(X) RM2(6)	0.385	(X) RM2(6)*,TSE(3)	0.480
Price	(I) M1(2)	0.326	(I) M1(2),TSE(7),R90(7), PFX(4)	0.612
	(X) M1(2)	0.276		

(cont'd)

[1] Models listed beside (I)/(X) include/exclude contemporaneous values of explanatory variables. Optimal lag lengths are given in parentheses.

[2] The monetary model is the preferred model unless otherwise indicated.

Table A:1 (cont'd)
Indicator Models[1]

	Monetary models	$\bar{R}^2$
GDP		
Nominal	(X) M1(2)	0.475
Real	(X) RM1(2)	0.310
Price	(X) M2(2)	0.624

Definitions

RTHC - real total household credit (consumer credit plus residential mortgage credit)

BLACB - business loans plus bankers' acceptances at chartered banks

SCB - short-term business credit at chartered banks (BLACB plus foreign currency loans to domestic residents)

STBC - short-term business credit at banks and non-banks

RMC - residential mortgage credit at banks and non-banks

TSE - TSE price index

R90 - 90-day commercial paper rate

PFX - Canadian/U.S. exchange rate (Canadian$/US$)

* denotes an aggregate with the sum of coefficients constrained to equal zero

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[1] Models listed beside (I)/(X) include/exclude contemporaneous values of explanatory variables. Optimal lag lengths are given in parentheses.

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Commentary

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by Douglas D. Purvis

In 1973, Stephen Goldfeld presented a paper on the demand for money at a Brookings Conference, and the discussant opened his remarks by commenting that Goldfeld had "done everything to the m^d equation except take it to the basement and beat it with a rubber hose." My reaction after this conference, and in particular after reading Allan's paper, is that that job is now well underway.

Allan presents the results of an ambitious and multi-faceted examination of the relationship between money, prices, interest rates, and income. Indeed, one reaction I had to reading the paper is that the examination is *too* multi-faceted. Some of the exercises are pursued without developing a great deal of the motivation and, at the same time, some of the interesting issues that arise are not pursued in any depth. Despite the well-defined set of questions it sets out to address, the paper would have benefited from more focus. In particular, while the explanation of each of the money-demand and the indicator models is quite thorough, the reconciliation featured so prominently in the title is, it seems to me, substantially incomplete. Nevertheless, the paper is a constructive start to the process of "pulling everything together," and presents a number of useful suggestions for further research that will contribute to the aforementioned reconciliation.

In Section 2, Allan looks at the empirical evidence on the two relations. Tables 1 through 4 summarize the results of estimating an equation for the growth rate of M2, using Almon lags to capture the dynamics. There are no real surprises here - we find that changes in income and prices lead changes in money. In the rubber hose tradition, one might have included some sensitivity tests, for example, pursuing a more detailed analysis of residuals. But I expect the result that (y, p) lead m would survive, as would the key additional result that m responds faster to price changes than to income changes.

The summary of the results on indicator models establishes the leading indicator role played by money, although it also confirms the "puzzle" noted in other papers at this conference that different monetary aggregates perform better for predicting nominal income and each of its two factors.

Sections 3 and 4 then explore the money-demand relationship in detail beginning in Section 3 with the partial-adjustment (P-A) model. In another conference, discussants might use most of their allotted time to discuss the lack of microfoundations of this specification; however, that doesn't seem appropriate here. In a different vein, I was surprised not to see any reference to the Brainard-Tobin "Pitfalls" model where partial adjustment is explicitly modelled as a multivariate process with explicit attention to the cross-equation restrictions implied by the wealth constraint; with this model, the interaction, say, between money and credit that is featured in some of Allan's later discussion can be treated within a "general equilibrium" framework.

Section 3.1 deals with an exploration of the partial-adjustment model. Implicitly, a central issue here is whether the dynamics of monetary adjustment reflect the slow adjustment of actual money balances towards a target that is moving quickly, or the quick adjustment of actual money balances towards a target that is moving slowly. Early literature (e.g., Feige, 1967)[1] addressed this in terms of regressive expectations, giving rise to a classic identification problem. In any event, even augmented by regressive expectations, the P-A model does not give rise to an explanation of the disparity in the speed with which money balances adjust to price and income changes; Crawford uses this failure to motivate the use of permanent income (y^P) as the scale variable in the P-A model; in the y^P/P-A model, money balances adjust towards target balances at a constant rate, but the target responds differentially to changes in prices and changes in real income.

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[1] Edgar L. Feige, "Expectations and Adjustments in the Monetary Sector." *American Economic Review* 57 (May 1967): 462-473.

This is a promising line of enquiry, but its implementation of course depends crucially on how best to represent y^P; in Section 4, Crawford develops the results for two popular alternative proxies - one draws on the consumption literature to specify y^P as a rational expectation of income, which in turn is assumed to follow a stochastic finite-order autoregressive process, while the other is a more simple mechanical representation of y^P as an infinite lag on past income.

The former approach gives rise to a reasonable set of estimates, but there arises an anomaly in that "money balances show a greater sensitivity to lagged income than can be attributed to the rational expectations proxy for permanent income." Crawford suggests that this may be one reason for income leading money in the money-demand equations while money leads income in the indicator models, and turns to examining the infinite-lag representation of y^P. He shows that these yield results similar to the model with rational expectations augmented by transitory income, and suggests therefore that the infinite-lag representation proxies for both permanent income and transitory income.

It seems to me that it would have been useful, at this point, to explore instead the money/y^P relationship in more detail in the context of the rational expectations approach. For example, as we were advised earlier "... indicator models of spending demonstrate that lagged money also contains useful information for predicting the future path of income." This is central to the question at hand, as the role of lagged money in influencing y^P may be an important part of the desired reconciliation, yet this is not explored.

Section 5 turns to indicator models with fixed prices. There are two interesting results here. One is that monetary policy reaction functions can help explain the m-leads-y fact. However, more might have been done with this, especially in research being carried out at the central bank where, presumably, there is above-average information about the nature of the reaction function. After all, it seems that the last 20 years have been characterized by some changes in the monetary policy reaction function, and some explanation of whether the evidence is consistent with these changes in regime could help identify whether this is an important source of the m-leads-y fact.

The heart of the model in Section 5 is contained in equations (23) and (24) along with the reaction function, equation (25). There are a number of sources for the dynamics: lagged r and y in the IS equation, partial adjustment of money demand, permanent income in money demand, and the policy reaction function which involves partial adjustment of the target money-growth rate and base drift. The desired reconciliation lies in the identification of the roles played by these various factors - a daunting task to say the least. Rather than pursuing this task, Allan chooses instead to compare the results from the base model with those that arise from the inclusion of credit variables.

This yields the second result - that credit variables also serve as leading indicators, but not at the expense of money. Money is *not*, by this evidence, serving as a proxy for credit. Mishkin's balance sheet effect is then discussed as an explanation of this result, but is not explicitly tested. This is a point where a joint money-demand/consumption model might prove very useful, as the recent literature on consumption suggests some, perhaps surprising, importance be attributed to liquidity constraints.

Section 6 then explores variable-price versions of the indicator model, one with market clearing and one with multi-period contracts. The theoretical results are not surprising. Market clearing eliminates any potential role for money as a leading indicator of real income, although it does help predict the price level. Multi-period contracts generate sluggish nominal adjustment in response to money shocks, and therefore reinstate a role for such shocks to influence future real income. However, no empirical evidence is provided to help us understand the role of this supply-side phenomenon or its interaction with expectations formation and the reaction function.

While there is much to be learned from this interesting and ambitious paper, I think it is not unfair to say that the results Allan presents are suggestive, but well short of conclusive. It is too soon to put the rubber hose away!

General Discussion

David Longworth began by pointing out that the absence of any discussion of the Brainard-Tobin model probably reflected the fact that the Bank's experience with that approach during the model-building period of the 1970s had been disappointing. When Doug Purvis noted that that application had been to work on the flow of funds, Longworth replied that it had also touched on money demand. Pierre Fortin suggested that further work should look for the source of the differences in lag length on prices and output in the money-demand function. He wondered if the use of seasonally adjusted data might be an explanation and recommended trying raw data.

Charles Adams asked whether the reaction function argument should not lead to a *negative* relationship between money growth and the growth of real income, as rapid money growth leads the central bank to tighten monetary conditions, with a subsequent slowdown in output growth. Allan Crawford suggested that this was an empirical question, that the first lag would have the negative impact suggested by Adams only if $\delta < \tau$ (the inertia of money demand is less than the gradualism parameter in the central bank reaction function).

Charles Freedman noted that, although in Crawford's model the short-run desired money-growth path adjusts to actual growth, this is in terms of rates of change. With a level target things are different. In fact, modelling growth rates may not capture the reaction function if the authorities take levels into account (and therefore do not allow base drift).

Pierre Duguay pointed out that the Crawford explanation does not need to be couched in growth-rate terms, the same result would follow from the assumption that the central bank would return the money stock gradually to a level target. He agreed with Charles Adams, however, that the reaction function explanation is more likely to produce a negative relationship between money and income, for the central bank would not consciously set $\tau < \delta$. The Crawford explanation must thus assume that the central bank operates with an overestimate of δ and that what it interprets as a slow process of adjustment of money demand might be a historical accident or the result of its own unduly slow reaction.

Steve Poloz pointed out that although changes in policy regime will affect parameters of indicator models if the reaction function story is true, this is not unique to indicator models; money-demand function coefficients would also change.

Pierre Fortin suggested that, with everything correlated with everything else, money's performance in the indicator models may just reflect omitted variables. Moreover, referring to a recent paper by John McCallum, he thought credit might exert a highly nonlinear impact of credit restraints at both the micro and macro levels. Crawford noted that he had included credit in some tests and it did not eliminate money. He thought an important group of omitted variables were those that would take into account the openness of the economy.

John McCallum argued that regime-switching was very important. During the 1976 to 1981-82 period, τ was clearly zero, but subsequently M1 has supposedly not been a target, so it should not explain anything. Crawford cited Patrice Muller's indicator-model work, which showed that real M1 worked better at explaining real GDP in the period prior to 1982, but retained significant explanatory power afterward (although the lagged dependent variable became more important). He drew attention to a footnote in which he had pointed out that the leading indicator role is not restricted to a regime with formal monetary targets, as long as money is on the informal "checklist" of variables monitored by the Bank. Muller emphasized that M1's role is quite strong in the 1984-89 period, i.e., after the major money-demand innovations were completed.

Tiff Macklem asked whether the single-equation restrictions on the coefficients of the money-demand function had been tested; i.e., that equation (22) implied that the coefficient on r_t was negative and that on r_{t-1} was positive. He added that it had not held in his own work. Crawford noted that it had not held in his either.

Charles Freedman wondered if the reaction function argument for including lagged money in the indicator model was a proxy for contemporaneous interest rates. Crawford replied that including the current interest rate did not completely eliminate lagged money.

Peter Howitt was puzzled by the stability of the indicator models, given the regime changes and the shifts in money demand. Fortin suggested that shifts are not as significant a problem in growth-rate terms, because they only give rise to errors in a small number of quarters. Freedman noted that this was also the case for money demand. Longworth pointed out that for M1 it was possible to use a demand function in levels with only a small number of shift variables. Freedman made the point that ignoring shifts is not feasible when targeting monetary aggregates because of the credibility problem. Howitt added that this still left the authorities able to use the aggregates as indicators.

In his final reply, Crawford noted that the differential speed of adjustment to income and prices held up when longer lags on interest rates were used, although it was less important. His more recent work using a Flavin-type autoregressive approach to the permanent-income hypothesis (included in the revised paper) still gives the differential speeds of adjustment, but the difference between the reaction to prices and that to output is less.

SYNTHESIS OF MONEY-DEMAND AND INDICATOR MODELS

by Allan W. Gregory, Gregor W. Smith and Tony Wirjanto*

Introduction

In the following study, we will examine several questions about the relationship between standard models of the demand for money and indicator or forecasting models of real or nominal income.

The questions

To explore the issues involved in jointly interpreting evidence from estimated money-demand equations and from indicator or forecasting models of real or nominal income or output, several questions must first be addressed:

- How does one reconcile the relationships described by indicator models with those described by money-demand functions? For example, indicator models show that money leads income while demand functions traditionally have income leading money.
- Are the estimated indicator and money-demand models, when taken together, consistent with traditional views of the monetary transmission mechanism and the structure of the economy?
- If not, what do they suggest about the transmission mechanism and the structure of the economy?

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* *We thank Pierre Duguay, Peter Howitt and David Longworth for helpful criticisms of earlier versions, and Bruce Montador and Lea-Anne Solomonian for skilled editing.*

The following issues will also be examined:

(i) Why do both interest rates and money enter indicator models? For example, residuals from the money-demand equation for M2 may play a role in indicator models of spending. Does this role reveal something about misspecification, measurement error or money-stock exogeneity?

(ii) As noted above, money-demand models have income leading money, whereas indicator models suggest that money is a leading indicator of income. For example, the correlation between nominal output and lagged nominal money is large and the correlation between nominal money and lagged nominal output is also large. Can these facts be reconciled?

(iii) More specifically, there is very slow adjustment of M2 to real income (hence, the use of growth-rate specifications), yet M2 seems to have the highest contemporary correlation of any indicator (in quarterly data).

We will attempt to examine whether the resolution of these questions tells us anything about the transmission mechanism of monetary policy. In preparing this paper we have had access to a large body of prior research done by economists at the Bank of Canada. However, the properties of the indicator models that we study here are relatively simple and we do not attempt to explain the rich body of evidence presented in Muller (1989), for example.

We use only these basic properties: the fact that both money and interest rates enter indicator models and the lag dynamics of the two models. Although we do not study the different properties of the various monetary aggregates, we do use some of the Granger-causal relationships between real money and real output.

The exercise set for us was to integrate back from empirical indicator and money-demand models to see whether they follow from certain structures but not others. Our method was to set up a number of simple theoretical structures called data-generation processes (DGPs) and then derive the two models within these structures to see if the implications match reality. This method is outlined in Section 1.

In the analytical part of the paper (Section 2), the basic DGP is:

$$m_t = \alpha_2 y_t + \alpha_3 r_t + \varepsilon_t$$

$$y_t = \beta_1 y_{t-1} + \beta_2 r_{t-1} + \eta_t$$

where m is real money, y is real income and r is an interest rate. These could be in levels or growth rates and could be regarded as LM and IS curves, respectively. The first part of the paper assumes nominal interest rate changes are real interest rate changes (π^e is constant in Canada) or that nominal interest rates affect real output. Notice that the money-demand relation in the structure is static and that lagged money does not enter the IS curve. Starting from the basic DGP, we go on to study the implied money-demand and indicator projections under various exogeneity and measurement assumptions. Given this simple DGP, if the nominal interest rate is exogenous, then for lagged money to enter the indicator model and for realistic dynamics in the money-demand model, we require two error-covariance properties: $\mathrm{cov}(\varepsilon_t,\eta_t) < 0$ and $\mathrm{cov}(\varepsilon_{t-1},\eta_t) > 0$.

Section 2 provides a sequence of examples (not mutually exclusive) of changes to the basic DGP that may rationalize these covariances. Within these example DGPs, the indicator and money-demand projections are found analytically. We first study this DGP with exogenous money. This interpretation can account for the indicator-model projections directly but may not be consistent with price and interest rate behaviour or with the dynamics of estimated money-demand equations.

In Section 2.1 we turn to an exogenous interest rate and allow for omitted variables. One possibility is that a variety of lagged variables enter indicator models because they provide information about the current period's interest rate. Section 2.2 modifies the basic DGP so that the demand for money depends on forecasted or expected income; this effect may explain the apparently slow adjustment in estimated money-demand equations. In Section 2.3, we retain the basic DGP and the assumption that there is an exogenous interest rate and allow for measurement error in real income. If the measurement error is a multi-step forecast error, it may give rise to a role for money in indicator models since money provides additional information on imperfectly measured past incomes. Moreover, a measurement error of the classical errors-in-variables type can cause apparent slow adjustment in money demand and both money and interest rates to enter an indicator model.

In Section 2.4 we consider a rather different DGP with some classical neutrality properties and with the real interest rate exogenous to monetary policy. We demonstrate here that nominal variables (whether interest rates or monetary aggregates) can have incremental predictive content even if there is no transmission mechanism if they react more quickly than real measures to underlying real shocks. This is shown in a DGP that mimics results of interest rate forecasting exercises as well.

One conclusion drawn in Section 2 is that a wide variety of structures (including those embodying a traditional central bank view of the transmission mechanism in which the central bank affects both money and income through its influence over nominal interest rates) may be qualitatively consistent with the dynamics of indicator and money-demand models.

Hence, in Section 3, we turn to some quantitative evidence. In this section, a nonstationary environment is used with numerical methods in a

DGP built around an intertemporal partial-adjustment model of money demand. We assume cointegration in money demand and calibrate a dynamic money-demand model. By construction, this DGP can reproduce a standard money-demand projection. It can also replicate an incremental predictive role for money (specifically, real M2) in an indicator model of real expenditure, although only with low probability. This result seems realistic.

Within this last DGP, standard single-equation estimation of partial-adjustment and error-correction mechanism models is inappropriate. So this laboratory can also be used to study estimation of money-demand equations alone. More generally, Section 3 illustrates the use of the artificial economy in simulation testing. For example, one could test structures by calculating the proportion of simulations in which they are able to mimic a test result or a pattern of VAR coefficients in actual data. Notwithstanding potential criticism of the DGP adopted in this section, it serves to illustrate formal numerical methods for testing quantitative matching of the properties of indicator and money-demand projections using an economic model.

1. Methods and Notation

In what follows, several DGPs are examined and the two types of regressions are embedded in them. The purpose is to see whether these DGPs are capable of reproducing the facts captured by the indicator-model and money-demand projections; a DGP that cannot do so can be rejected. These facts that we try to match include the presence of certain variables, the signs of coefficients and the apparent dynamics. The structures used are all quite simple - for example, they represent closed economies. In some cases, the implications of a structure for the two projections can be found analytically, while in other cases numerical methods seem more appropriate.

1.1 Recursive projection

In the analytical results, the basic tool is the recursive-projection formula (analogous to sequential OLS regression, the Kalman filter or conditional expectations under joint normality). For example, if y, m and r are jointly normally distributed, then:

$$E(y|m,r) = E(y|r) + E(y - E(y|r)|m - E(m|r)) , \qquad (1)$$

while under alternative probability distributions, one could think of these simply as linear projections. The last term in equation (1) measures the incremental predictive content of m.

1.2 Simulation estimation

In certain cases, working out the implied projection coefficients is difficult, and so numerical methods are used. Here, so-called artificial economy methods were employed: with this method, we embedded indicator and money-demand models in a stochastic economic model to see whether we could account for any apparent inconsistencies in their findings. This approach is indirect. A simulation model with known properties and structure was constructed and the two projections were fitted to the simulated data from this model or DGP. If the projection models behave as they do in historical data, then some tentative conclusions can be drawn about the historical structure from the numerical DGP.

Although some data are used in this paper, a portion of the econometric estimation is undertaken without using data directly, with estimates of the signs and magnitudes of parameters based on statistics calculated from artificial data - for example, ordinary least squares (OLS) coefficients or calculated test statistics for Granger-causality that correspond to those from empirical studies done at the Bank. The parameter values in a numerical theoretical model that can best reproduce those statistics constitute estimates of those underlying parameters. The same method, based on the simulated probability density function of the parameters in projections, could be used for testing.

1.3 Notation

The Greek letters denote parameters (values that characterize the DGP or structure), while other letters denote coefficients in projections or their probability limits (plims) since, for simplicity, we refer in the analytical results to population values. Unless otherwise noted, each error term in the structure is uncorrelated with the right-hand-side variables in the corresponding equation. M is nominal money, Y is nominal output, p is the price level (deflator), m is real money, y is real output (all in logarithms), r is a nominal interest rate, and i is a real interest rate. We work with the lag operator L, defined so that $L^s x_t = x_{t-s}$.

In Section 2 some simple data-generation processes are examined for consistency with the three issues outlined earlier; the methods are analytical. A more detailed numerical study in a specific DGP is then undertaken. This illustrates a method that could be used in more complicated (open economy) versions of the DGPs studied below. In the concluding section, some extensions are suggested.

2. Some Sample Linear Data-Generation Processes

To begin, we focus on the joint behaviour of real money, real income and interest rates. Suppose that m_t (real money), y_t (real income) and an interest rate r_t are stationary and have at least two moments. The simplest explanation for the presence of both lagged interest rates and lagged money in indicator models of spending is that money is causing both the other variables and that there is an additional transmission mechanism to y other than through r.

Now let us assume that M is exogenous in a simple DGP. The central bank influences the monetary base or some short-term interest rate, hence affecting M1 or M2 and thus p, y and also r, a market interest rate. The DGP is:

$$m_t = \alpha_2 y_t + \alpha_3 r_t + \varepsilon_t \tag{2}$$

$$y_t = \beta_1 y_{t-1} + \beta_2 r_{t-1} + \beta_3 m_{t-1} + \eta_t \tag{3}$$

where r and y are endogenous. We assume that $\text{cov}(\varepsilon_t, \eta_t) = 0$. But since r_t is endogenous, it may covary with each of these shocks so that equation (2) will not be a standard regression.

The reduced-form equations for output and the interest rate are:

$$\begin{aligned} y_t\,(1 - (\beta_1 - \beta_2\alpha_2/\alpha_3)L) = {} & (\beta_3 + \beta_2/\alpha_3)m_{t-1} \\ & + \eta_t - (\beta_2/\alpha_3)\varepsilon_{t-1} \end{aligned} \tag{4}$$

and

$$\begin{aligned} r_t = {} & m_t/\alpha_3 - \varepsilon_t/\alpha_3 - (\alpha_2/\alpha_3)[(\beta_3 + \beta_2/\alpha_3)m_{t-1} \\ & + \eta_t - (\beta_2/\alpha_3)\varepsilon_{t-1}] \cdot (1 - (\beta_1 - \alpha_2\beta_2/\alpha_3)L)^{-1} . \end{aligned} \tag{5}$$

Notice that from equation (5) r_{t-1} involves ε_{t-1} and that from equation (4) y_t also involves ε_{t-1}. Thus, if η and ε are zero-mean white noises, then by the recursive-projection formula (1), the sign of the coefficient on r_{t-1} in the regression of y_t on y_{t-1}, m_{t-1}, and r_{t-1} will be

$$\operatorname{sgn}[(-\beta_2/\alpha_3) \,.\, (-1/\alpha_3)] < 0 \tag{6}$$

so that in the indicator model, both lagged money and interest rates will enter and with signs that are observed empirically. Note that $\beta_2 \neq 0$ is, however, necessary. In fact,

$$\begin{aligned} E(y_t \,|\, y_{t-1}, m_{t-1}, r_{t-1}) &= E(y_t \,|\, y_{t-1}, m_{t-1}) \\ &\quad + E(y_t - E(y_t \,|\, y_{t-1}, m_{t-1}) \,|\, r_{t-1} \\ &\quad - E(r_{t-1} \,|\, y_{t-1}, m_{t-1})) \\ &= (\beta_1 - \beta_2\alpha_2/\alpha_3) y_{t-1} + (\beta_3 + \beta_2/\alpha_3) m_{t-1} \\ &\quad + E(\eta_t - (\beta_2/\alpha_3)\varepsilon_{t-1} \,|\, -\beta_1\varepsilon_{t-1}/\alpha_3 \\ &\quad - \alpha_2\eta_t/\alpha_3) \end{aligned} \tag{7}$$

using (4) and (5). The definition of ε_{t-1} from equation (2) then gives,

$$\begin{aligned} E(y_t \,|\, y_{t-1}, m_{t-1}, r_{t-1}) &= (\beta_1 - \beta_2\alpha_2/\alpha_3) y_{t-1} + (\beta_3 + \beta_2/\alpha_3) m_{t-1} \\ &\quad + \beta_2\alpha_2 y_{t-1}/\alpha_3 - \beta_2 m_{t-1}/\alpha_3 + \beta_2 r_{t-1} + \eta_t \\ &= \beta_1 y_{t-1} + \beta_3 m_{t-1} + \beta_2 r_{t-1} + \eta_t \end{aligned} \tag{8}$$

so that equation (3) is already a projection.

Since this last DGP essentially consists of the money-demand and indicator models, this result is particularly obvious. This view of money as being Granger-causally prior to interest rates and income is consistent with the indicator model and just restates this causality result. But we have also ignored variation in the price level and its endogeneity. One interpretation of money-demand dynamics is that they are the result of slow price adjustment (see Laidler, 1985; 1988). A further test would be to study the price equation resulting from this DGP, assuming slow adjustment of prices to changes in the money supply.

MacKinnon and Milbourne (1988) suggest such a test. They invert a Goldfeld-type money-demand equation and interpret it as a price equation. Thus

$$M_t - p_t = \alpha_2 y_t + \alpha_3 r_t + \alpha_4(M_{t-1} - p_{t-1}) + \varepsilon_t \qquad (9)$$

becomes

$$p_t = M_t - \alpha_2 y_t - \alpha_3 r_t - \alpha_4(M_{t-1} - p_{t-1}) - \varepsilon_t \qquad (10)$$

which they find little support for empirically. Price equations (or inflation-indicator models) do not seem to work this way. However, Milbourne (1989) suggests that observed low correlations between nominal money and nominal income in the short run provide support for exogenous buffer-stock money. Including a monetary reaction function and measurement error (discussed below) could also complicate the interpretation of this kind of evidence.

Another aspect of the question concerns the behaviour of interest rates. Sims (1980) and Litterman and Weiss (1985) report postwar evidence from several countries indicating that real interest rates are causally prior to money. In the remainder of this section it will be assumed that this is the case. Specifically, we assume that the central bank controls r_t (a nominal interest rate), and thus affects m_t (real balances), as well as y_t (real output). We first set down simple DGPs that assume that influence over nominal interest rates provides influence over real interest rates, so we do not make the distinction explicit. Later, we examine an extreme case in which monetary policy cannot affect real interest rates.

Under what circumstances can both money and interest rates Granger-cause output in this environment? Consider the following DGP:

$$m_t = \alpha_2 y_t + \alpha_3 r_t + \varepsilon_t \qquad (11)$$

$$y_t = \beta_1 y_{t-1} + \beta_2 r_{t-1} + \eta_t \qquad (12)$$

where we assume that the errors ε and η are each normally and identically distributed. One could use growth rates of the variables or add a lagged dependent variable in the money-demand equation. The simplest way to view this DGP is as if r were an exogenous short-term interest rate and the two equations described money demand and an IS curve. Thus, m and y are endogenous variables. We now allow $\mathrm{cov}(\eta_t, \varepsilon_{t-s}) \neq 0$.

With this DGP, the indicator-model projection is:

$$\text{(im) } y_t = b_1 y_{t-1} + b_2 r_{t-1} + b_3 m_{t-1} + u_t \, . \qquad (13)$$

From the DGP :

$$\begin{aligned} E_{t-1} y_t &= \beta_1 y_{t-1} + \beta_2 r_{t-1} + E(\eta_t \mid \varepsilon_{t-1}) \\ &= \beta_1 y_{t-1} + \beta_2 r_{t-1} + E(\eta_t \mid m_{t-1} - \alpha_2 y_{t-1} - \alpha_3 r_{t-1}) \end{aligned}$$

(so that the error from the money-demand structure enters the indicator model)

$$\begin{aligned} &= \beta_1 y_{t-1} + \beta_2 r_{t-1} + \delta(m_{t-1} - \alpha_2 y_{t-1} - \alpha_3 r_{t-1}) \\ &= (\beta_1 - \delta\alpha_2) y_{t-1} + (\beta_2 - \delta\alpha_3) r_{t-1} + \delta m_{t-1} \qquad (14) \end{aligned}$$

where $\mathrm{plim}\ \delta = \mathrm{cov}(\eta_t, \varepsilon_{t-1})/\mathrm{var}(\varepsilon_t)$ as in any linear regression. We assume that the underlying error-covariance matrix is constant.

In empirical versions of equations like this, $\delta > 0$, indicating that the error covariance is positive. If we compare the indicator model to equation (12) in the DGP, then, since $\alpha_3 < 0$, the apparent role of the lagged interest rate is reduced (becomes a negative number smaller in absolute value than, say, β_2). Note also that money leads income in this projection.

Let us also examine the money-demand projection under this DGP:

$$\begin{aligned} E_t m_t &= \alpha_2 y_t + \alpha_3 r_t + E(\varepsilon_t \mid \eta_t) \\ &= \alpha_2 y_t + \alpha_3 r_t + \delta'(y_t - \beta_1 y_{t-1} - \beta_2 r_{t-1}) \\ &= (\alpha_2 + \delta')y_t - \delta'\beta_1 y_{t-1} + \alpha_3 r_t - \delta'\beta_2 r_{t-1} \qquad (15) \end{aligned}$$

where $\delta' = \text{cov}(\eta_t,\varepsilon_t)/\text{var}(\eta_t)$. The money-demand projection yields a simple distributed-lag model so that income leads money. Also, $\beta_1 > 0$ and $\beta_2 < 0$ in a standard interpretation of the DGP. Thus, for the coefficients in this projection not to alternate in sign - as they do not (see Crawford, 1990, in this volume) - it must be the case that $\delta' < 0$.

Notice that these results also would apply were we to think of the DGP as:

$$m_t = \alpha_2 y_t + \alpha_3 r_t + \varepsilon_t \qquad (16)$$

$$y_t = \beta_1 y_{t-1} + \beta_3 m_{t-1} + \eta_t \qquad (17)$$

with r influencing m, which in turn affects y. The two projections are:

$$\begin{aligned} E_{t-1} y_t &= (\beta_1 - \delta\alpha_2)y_{t-1} + (\beta_3 + \delta)m_{t-1} - \delta\alpha_3 r_{t-1}) \\ E_t m_t &= (\alpha_2 + \delta')y_t - \delta'\beta_1 y_{t-1} + \alpha_3 r_t - \delta'\beta_3 m_{t-1} \qquad (18) \end{aligned}$$

with δ and δ' appropriately defined. It is again straightforward to show that realistic indicator and money-demand models require that $\text{cov}(\eta_t,\varepsilon_{t-1}) > 0$ and $\text{cov}(\eta_t,\varepsilon_t) < 0$.

In this simple example, $\text{cov}(\eta_t,\varepsilon_{t-1}) \neq 0$ is necessary for both interest rates and money to enter the indicator model; $\text{cov}(\eta_t,\varepsilon_t) \neq 0$ also has implications for the money-demand model. However, thus far, these results are truisms. The question is: Why might $\mathrm{cov}(\eta_t, \varepsilon_{t-1}) > 0$ and $\mathrm{cov}(\eta_t, \varepsilon_t) < 0$? Notice also that the larger δ' is in absolute value, the slower the adjustment in the money-demand projection, while the larger δ is, the larger the effect of lagged money in the indicator model. This relates to issue (iii) in the Introduction. Next, we examine several (not mutually exclusive) ways in which our assumed DGP might be altered to account for these covariances and try to work out some ways of distinguishing among them.

2.1 Reaction functions and omitted variables in the DGP

From the above results, a variable that enters only the money-demand equation in the structure (or DGP) should enter the indicator model with the opposite sign. Conversely, a variable that enters only the income equation in the DGP should enter the money-demand projection with the same sign. For example, if the DGP is:

$$m_t = \alpha_2 y_t + \alpha_3 r_t + \varepsilon_t + \alpha_4 z_t \tag{19}$$

$$y_t = \beta_1 y_{t-1} + \beta_2 r_{t-1} + \eta_t + \beta_4 w_t \tag{20}$$

then, under $\mathrm{cov}(\eta_t, \varepsilon_{t-1}) > 0$ and $\mathrm{cov}(\eta_t, \varepsilon_t) < 0$, z_t will enter the indicator model with coefficient $-\delta\alpha_4$ and w_t will enter the money-demand model with coefficient $-\delta'\beta_4$. An example of z_t might be a dummy variable capturing some shift in the money-demand structure.

Crawford (1990, in this volume) suggests the possibility that both m_{t-1} and r_{t-1} enter the indicator model (i.e., $\mathrm{cov}(\eta_t, \varepsilon_{t-1}) > 0$) because the indicator model is written as a forecasting equation, while actual income depends on current interest rates. If lagged money helps forecast the current interest rate (as under a reaction function), then it may help forecast income.

For example, suppose that the DGP is

$$m_t = \alpha_2 y_t + \alpha_3 r_t + \varepsilon_t \tag{21}$$

$$y_t = \beta_1 y_{t-1} + \beta_2 r_{t-1} + \eta_t + \beta_4 r_t \tag{22}$$

$$r_t = \psi m_{t-1} + \upsilon_t \tag{23}$$

where equation (23) is a reaction function.[1] Let us examine the two projections under this DGP. The indicator model is:

$$\begin{aligned} E_{t-1}y_t &= \beta_1 y_{t-1} + \beta_2 r_{t-1} + E(\eta_t + \beta_4 r_t \mid m_{t-1} - \alpha_2 y_{t-1} - \alpha_3 r_{t-1}) \\ &= \beta_1 y_{t-1} + \beta_2 r_{t-1} + E(\eta_t \mid \varepsilon_{t-1}) + E(\beta_4 r_t \mid m_{t-1} - \alpha_2 y_{t-1} - \alpha_3 r_{t-1}) \\ &= (\beta_1 - \delta\alpha_2) y_{t-1} + (\beta_2 - \delta\alpha_3) r_{t-1} \\ &\quad + \delta m_{t-1} + \beta_4 \psi m_{t-1} \, . \end{aligned} \tag{24}$$

If $\delta = 0$, then

$$E_{t-1}y_t = \beta_1 y_{t-1} + \beta_2 r_{t-1} + \beta_4 \psi m_{t-1} \, . \tag{25}$$

Crawford notes that while β_4 normally would be expected to be negative, ψ could also be negative, so that lagged money could have a positive effect on predicted income, as is the case in indicator models (see also the reaction functions in Barro, 1989). This would give $\text{cov}(\beta_4 r_t, \varepsilon_{t-1}) > 0$ as required.

There are several ways to explore this possibility. One is to examine the regression of r_t on $\hat{\varepsilon}_{t-1}$ for a positive coefficient. Such a coefficient may make sense as part of a reaction function: if the monetary aggregate grew at a faster rate last period than historically predicted from interest rates and income, then there will be a positive innovation in this period's interest rate.

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[1] Note that in the DGP with which we began (equations (11) and (12)), η_t would have included the effect of the omitted variable r_t.

Second, by the same logic, any variable that helps forecast interest rates should enter the indicator model. For example, the reaction function might also adjust r_t to recent inflation or exchange rate changes; these would thus appear in the indicator model with the opposite signs.

Third, this proposed DGP could be examined by studying its implied money-demand projection as well:

$$\begin{aligned} E_t m_t &= \alpha_2 y_t + \alpha_3 r_t + E(\varepsilon_t \mid y_t - \beta_1 y_{t-1} - \beta_2 r_{t-1} \\ &\quad - \beta_4 r_t, r_t - \psi m_{t-1}) \\ &= \alpha_2 y_t + \alpha_3 r_t + \delta'(y_t - \beta_1 y_{t-1} - \beta_2 r_{t-1} - \beta_4 r_t) \\ &\quad + \delta_2(r_t - \psi m_{t-1}) \\ &= (\alpha_2 + \delta')y_t - \delta'\beta_1 y_{t-1} + (\alpha_3 - \delta'\beta_4 + \delta_2)r_t \\ &\quad - \delta'\beta_2 r_{t-1} - \delta_2 \psi m_{t-1} \end{aligned} \tag{26}$$

where $\delta' < 0$ if $\mathrm{cov}(\eta_t, \varepsilon_t) < 0$ and δ_2 is a similarly defined coefficient with $\delta_2 > 0$ if $\mathrm{cov}(\varepsilon_t, \upsilon_t) > 0$. (Note that in the recursive money-demand projections described so far, we have assumed that y_{t-1} and r_{t-1} are already in the information set; this is not a crucial simplification.) Recall that ψ must be negative for the reaction function DGP to rationalize the results of the indicator-model projection. In empirical versions of the money-demand projection, the lagged dependent variable enters with a positive coefficient. Thus, δ_2 must be positive; i.e., positive money-demand shocks are associated with higher-than-predicted interest rates in the current period. This might suggest that a demand function, as opposed to a reaction function, is being identified.

Fourth, it could also be the case that m_t, rather than r_t, is omitted from the y_t equation in the DGP. Then both m_{t-1} and r_{t-1} might be helpful in forecasting y_t and hence enter the indicator-model projection. This brings us back to the DGP in equation (3).

2.2 Expectations in the demand for money

Crawford (1990) discusses a fourth stylized fact in addition to those listed in the Introduction: in money-demand equations, nominal money holdings seem to adjust more slowly to changes in real income than to changes in prices. In the standard partial-adjustment equation, the adjustment speeds are the same. A traditional interpretation has been that adjustment occurs at the same rate to prices and to a smoothed income target (for example, expected income or permanent income) as opposed to current income. Suppose that

$$m_t(1-\lambda L) = \alpha_2 \bar{y}_t + \varepsilon_t \qquad (27)$$

where m_t is real balances (for simplicity), λ arises from partial adjustment and $\bar{y}_t$ is the smoothed income series. A traditional model is

$$\bar{y}_t = y_t/(1-\alpha L) \qquad (28)$$

i.e., an infinite moving average with geometrically declining weights. Then, combining equations (27) and (28) gives

$$m_t(1-\lambda L)(1-\alpha L) = \alpha_2 y_t + \varepsilon_t(1-\alpha L)\ . \qquad (29)$$

This equation is consistent with slow adjustment to current income, but it also requires that there be a moving average in the residuals when equation (29) is estimated (see Waud, 1968; Doran and Griffiths, 1978). This auxiliary prediction for the money-demand model may not hold empirically. Laidler

(1985) provides a discussion of this "expectations" interpretation of money-demand dynamics.

An alternative is that $\tilde{y}_t = \theta_0 y_t + \theta_1 y_{t-1} + \theta_2 y_{t-2}$, an example of a finite-order autoregression. This could arise if m_t is held on the basis of expected future income, itself a function of lagged income. This may make sense if there are adjustment costs; the value of the target may change while adjustment is taking place. In this second case, the distributed-lag coefficients in the money-demand projection are normally viewed as amalgams of structural parameters (e.g., the income elasticity of money demand) and of the parameters in the AR(3) (in this case) representation of $\{y_t\}$.

An equally straightforward example is given by modifying our simple linear DGP to:

$$m_t = \alpha_2 E_{t-1} y_t + \alpha_3 r_t + \epsilon_t \tag{30}$$

$$y_t = \beta_1 y_{t-1} + \beta_2 r_{t-1} + \eta_t \, . \tag{31}$$

This modification to make money holdings depend on expected income will not account for the role of lagged money in the indicator model. In the money-demand projection:

$$E(m_t \mid y_t, y_{t-1}, r_t, r_{t-1}) = c_1 y_t + c_2 y_{t-1} + d_1 r_t + d_2 r_{t-1} \, , \tag{32}$$

where plim $c_1 = 0$, plim $c_2 = \alpha_2 \beta_1$, plim $d_1 = \alpha_3$, and plim $d_2 = \alpha_2 \beta_2 < 0$. This effect can account for part of the slow adjustment, as in Goodfriend (1985).

A simple test of this alternative explanation of the dynamics involves an application of the Lucas critique. First, suppose that the money-demand model and the income process are estimated jointly. Then suppose that the coefficients in the latter (the β's) change during the sample. Finally, suppose that the coefficients in the former (the c's) do not change; the model can then be rejected (e.g., in the demand for money, see Hendry, 1988). An alternative way of studying the smoothing or intertemporal partial-adjustment model will be considered later in Section 3.

2.3 Income-measurement error

Recall that rationalizing the findings of the indicator and money-demand models in the original DGP required $\mathrm{cov}(\eta_t, \epsilon_{t-1}) > 0$ and $\mathrm{cov}(\eta_t, \epsilon_t) < 0$. A simple interpretation of these covariances is that they are the result of measurement error. For example, their signs imply $\mathrm{cov}(\eta_t, \epsilon_t - \epsilon_{t-1}) < 0$; when income (relative to trend, perhaps) is high, money growth is low, compared to the predicted values in the DGP. This pattern could result from different seasonal patterns in the two series $\{\eta_t\}$ and $\{\epsilon_t - \epsilon_{t-1}\}$. Or it could arise from different time-series properties in the revisions to the monetary aggregates (see Milbourne and Smith, 1989) and to the national accounts. However, the findings summarized in indicator and money-demand models seem to hold in both seasonally adjusted and unadjusted data and in both revised and unrevised data; hence, the impact of these factors seems empirically slight.

However, serendipitous covariances between measurement errors in income and money are not required for measurement error to be part of an explanation for the facts we are seeking to synthesize. To see a further example of the effects of measurement error, suppose that the DGP is again

$$m_t = \alpha_2 y_t + \alpha_3 r_t + \epsilon_t \,. \tag{33}$$

$$y_t = \beta_1 y_{t-1} + \beta_2 r_{t-1} + \eta_t \,. \tag{34}$$

We assume that $\text{cov}(\varepsilon_t, \eta_t) = 0$. Suppose that the investigator measures income with an error that enters into η_t, and that the error is not simply a one-step forecast error. As an example, suppose that there are measurement (forecast) errors in both current and lagged income so that the information set at time t-1 is $\{y_{t-2}, r_{t-1}, m_{t-1}\}$. Thus, $E_{t-1}y_{t-1} = \beta_1 y_{t-2} + \beta_2 r_{t-2}$. By the chain rule of forecasting:

$$E_{t-1}y_t = \beta_1 E_{t-1}y_{t-1} + \beta_2 r_{t-1} = \beta_1^2 y_{t-2} + \beta_1\beta_2 r_{t-2} + \beta_2 r_{t-1}$$

so that

$$y_t - E_{t-1}y_t = \eta_t + \beta_1\eta_{t-1}, \tag{35}$$

which is a first-order moving average. Meanwhile, in the money-demand projection:

$$E_t m_t = \alpha_2 E_t y_t + \alpha_3 r_t = \alpha_2(\beta_1 y_{t-1} + \beta_2 r_{t-1}) + \alpha_3 r_t \tag{36}$$

and

$$m_t - E_t(m_t) = \varepsilon_t + \alpha_2\eta_t, \tag{37}$$

since y_{t-1} is known at time t. Let us examine the covariance between the two composite error terms. First, since $\text{cov}(\varepsilon_t + \alpha_2\eta_t, \eta_t + \beta_1\eta_{t-1}) = \alpha_2\sigma_\eta^2 > 0$, this measurement error cannot account for slow adjustment in the money-demand equation in measured data. Second, $\text{cov}(\varepsilon_{t-1} + \alpha_2\eta_{t-1}, \eta_t + \beta_1\eta_{t-1}) > 0$, so there will be a role for lagged money in the indicator model. Since y_{t-1} is measured imperfectly at time t-1, information on m_{t-1} is useful in the indicator model.

So far, we have considered the case in which measured income can be thought of as expected or predicted income. A second case would be one in which the covariance between the measurement error and the actual value y_t

is zero, which is a classical errors-in-variables model. Granger-causality tests in this case are discussed by Sargent (1987, pp. 346-348). Suppose that

$$y_{mt} = y_t + \omega_t \tag{38}$$

with $E\omega_t\, y_{t-s} = 0 \;\forall\; t,s$. In other words, the error is orthogonal to the true value rather than to the measurement or prediction. Assume also that $E\omega_t m_{t-s} = 0 \;\forall\; t,s$. For simplicity, interest rates are excluded since nothing hinges on them directly. The DGP is

$$m_t = \alpha_2 y_t + \varepsilon_t \tag{39}$$

$$y_t = \beta_1 y_{t-1} + \eta_t \tag{40}$$

$$y_{mt} = y_t + \omega_t \tag{41}$$

with ω, η and ε mutually and serially uncorrelated. We are interested in the projection $E(y_t \mid y_{mt-1}, m_{t-1})$, which we write as $E_{t-1}y_t = b_1 y_{mt-1} + b_3 m_{t-1}$. To calculate the probability limits of the projection coefficients, note that:

$$y_{mt} = \eta_t(1-\beta_1 L)^{-1} + \omega_t \tag{42}$$

$$y_{mt-1} = \eta_t L(1-\beta_1 L)^{-1} + \omega_{t-1} \tag{43}$$

$$m_t = \alpha_2 \eta_t (1-\beta_1 L)^{-1} + \varepsilon_t \tag{44}$$

so that

$$\begin{aligned} \mathrm{var}(m_{t-1}) &= \alpha_2^2 \sigma_\eta^2/(1-\beta_1^{\,2}) + \sigma_\varepsilon^2,\ \mathrm{var}(y_{mt}) = \mathrm{var}(y_{mt-1}) \\ &= \sigma_\eta^2/(1-\beta_1^{\,2}) + \sigma_\omega^2 , \end{aligned}$$

$$\mathrm{cov}(y_{mt}, y_{mt-1}) = \beta_1\sigma_\eta^2/(1-\beta_1{}^2),\ \mathrm{cov}(y_{mt}, m_{t-1}) = \alpha_2\beta_1\sigma_\eta^2/(1-\beta_1{}^2)\ ,$$

and

$$\mathrm{cov}(y_{mt-1}, m_{t-1}) = \alpha_2\sigma_\eta^2/(1-\beta_1{}^2)\ .$$

For easier reading, consider a special case in which $\alpha_2 = 1$. The usual normal equations give:

$$\mathrm{plim}\ b_1 = \beta_1/[1 + \sigma_\omega^2/\sigma_\varepsilon^2 + (1-\beta_1{}^2)\sigma_\omega^2/\sigma_\eta^2] \tag{45}$$

$$\mathrm{plim}\ b_3 = \beta_1/[1 + \sigma_\varepsilon^2/\sigma_\omega^2 + (1-\beta_1{}^2)\sigma_\varepsilon^2/\sigma_\eta^2] > 0\ . \tag{46}$$

One can also show that if $\sigma_\omega^2 = 0$, then $\mathrm{plim}\ b_1 = \beta_1$ and $\mathrm{plim}\ b_3 = 0$.

The same method can be used to find the coefficients in a distributed-lag model of the demand for money: $E(m_t \mid y_{mt}, y_{mt-1}) = c_1 y_{mt} + c_2 y_{mt-1}$. In this projection:

$$\mathrm{plim}\ c_1 = \alpha_2\sigma_\eta^2(\sigma_\eta^2 + \sigma_\omega^2)/[\sigma_\eta^2(\sigma_\eta^2 + 2\sigma_\omega^2) + (\sigma_\omega^2)^2\,(1-\beta_1^2)]\ . \tag{47}$$

$$\mathrm{plim}\ c_2 = \alpha_2\beta_1\sigma_\eta^2\sigma_\omega^2/[\sigma_\eta^2(\sigma_\eta^2 + 2\sigma_\omega)^2 + (\sigma_\omega^2)^2\,(1-\beta_1^2)] > 0\ . \tag{48}$$

If $\sigma_\omega^2 = 0$, then $\mathrm{plim}\ c_1 = \alpha_2$ and $\mathrm{plim}\ c_2 = 0$. The coefficients in a partial-adjustment projection $E(m_t \mid y_{mt}, m_{t-1})$ could also be calculated.

This errors-in-variables problem does produce the facts we seek to mimic; it accounts for lagged money in the indicator model and lagged income in the money-demand model. Again, the scale of these effects depends on σ_ω^2. Moreover, it seems quite likely that measurement error comes from a time-varying distribution, so that its effect on the two projections is likely to vary over time. Further research could try to quantify this effect.

Let us try some simple calculations to gauge whether this possibility is anything more than a curiosity. For illustration, suppose that the DGP has parameters $\alpha_2 = 2/3$, $\beta_1 = 0.9$, $\sigma_\eta^2 = \sigma_\varepsilon^2 = 1$, $\sigma_\omega^2 = 0.5$. Then, the plims of the two projections are:

$$\begin{aligned} E(y_t \mid y_{mt-1}, m_{t-1}) &= 0.564 y_{mt-1} + 0.282 m_{t-1} \\ E(m_t \mid y_{mt}, y_{mt-1}) &= 0.488 y_{mt} + 0.147 y_{mt-1} \,. \end{aligned} \tag{49}$$

These projections are unrealistic in some ways, but the example demonstrates that the effect of the measurement error depends on the coefficients of the structure as well as on the scale of the error itself. In the projections of observable variables, income leads money in the money-demand projection, money leads income in the indicator model, and both money and interest rates (for the more general DGP) enter the indicator model.

2.4 Spurious Granger-causality

One straightforward conclusion so far is that evidence from the time-series behaviour of all four variables - M, r, y, and p (possibly including a reaction function) - is necessary in order to make deductions about the transmission mechanism. It may be the case that the issues listed in the first section simply cannot discriminate among various views of the transmission mechanism. In this four-variable system, each variable will typically Granger-cause each other variable. Again, there will be many possible explanations for this interdependence. A more dramatic scenario would involve finding that Granger-causality did *not* hold. We conclude this section by studying a DGP designed to mimic such a situation and deriving an indicator projection within it.

In postwar data for a number of countries, Sims (1980) and Litterman and Weiss (1985) have observed a striking fact: real interest rates seem to

Granger-cause output, prices and money but not be Granger-caused by them. They interpret this observation as casting some doubt on the idea that monetary policy affects money and then indirectly influences real output via interest rates, whereas this pattern of Granger-causal relations presumably might be found if a central bank influences interest rates directly rather than a monetary aggregate (i.e., the Granger-causality results alone are consistent with models with or without neutrality). In any case, up to this point our simple DGPs have assumed that nominal interest rate movements are real rate movements or that lagged nominal rates influence real output. Litterman and Weiss suggest a simple linear DGP that is consistent with this causality evidence in the four-variable system. The DGP has the following classical form:

$$y_t = \beta_1 y_{t-1} + \beta_2 i_{t-1} + \eta_t \tag{50}$$

$$M_t - p_t = \alpha_2 y_t + \alpha_3 r_t \tag{51}$$

$$r_t = i_t + E_t(p_{t+1} - p_t) \tag{52}$$

$$i_t = \kappa i_{t-1} + \upsilon_t \tag{53}$$

where i_t is a real interest rate. The model can be closed with a policy rule (reaction function) for either the nominal interest rate r_t or the nominal money supply M_t. As an example, consider a feedback rule for the former:

$$r_t = \gamma \pi_t , \ \gamma > 0 \tag{54}$$

where $\pi_t = p_t(1\text{-}L)$, so that the authorities react to inflation by raising nominal interest rates. This rule allows us to solve for $\{p_t\}$ and $\{M_t\}$. Using equation (54) in (52) gives:

$$\gamma \pi_t = i_t + E_t\pi_{t+1} \tag{55}$$

which can be solved by standard methods to give

$$\pi_t = i_t(\gamma-\kappa)^{-1} \tag{56}$$

provided $\gamma > \kappa$. Thus, the reduced-form equation for the nominal interest rate is:

$$r_t = \gamma\ i_t(\gamma-\kappa)^{-1} = \gamma(\gamma-\kappa)^{-1}\upsilon_t/(1-\kappa L)\ . \tag{57}$$

Output evolves according to

$$\begin{aligned} y_t &= \beta_1 y_{t-1} + \beta_2 i_{t-1} + \eta_t \\ &= \beta_1 y_{t-1} + \beta_2 \upsilon_{t-1}/(1-\kappa L) + \eta_t\ . \end{aligned} \tag{58}$$

It is straightforward to show that r_{t-1} helps predict y_t, given y_{t-1}, since it provides information on υ_{t-1} which y_{t-1} does not. The coefficient on r_{t-1} will be $\beta_2(\gamma-\kappa)/\gamma$. In fact, any nominal variable will serve as a good indicator in this environment.

This example is *not* set up to examine the issue of a separate indicator role for money. Instead, it makes the point that nominal variables (nominal interest rates or monetary aggregates) Granger-cause real output because an omitted variable - the real interest rate - causes both. This possibility is not surprising, but it is interesting in this DGP because: (i) the DGP was rigged to reproduce other historical evidence on Granger-causal relationships, and

(ii) the key feature is that the monetary sector reacts more rapidly than the real sector to shocks to the real interest rate (see Fama, 1982) and, hence, provides good indicators. This feature does not seem pathological. However, the indicator model provides no information about the transmission mechanism in this extreme classical economy.

One could amend this classical DGP with different reaction functions or with different models of aggregate supply and retain the property that nominal variables would be useful indicators. Adherents of a traditional central bank view of the transmission mechanism might argue that some further assumptions or implications of this structure would not hold. This may be so; the point of this example is that perhaps indicator models alone cannot distinguish among structures or reveal much about the transmission mechanism.

In this section, we have studied a number of ways in which simple DGPs may account for both interest rates and money having predictive ability in a real indicator model. We have shown that the presence of monetary aggregates in such models can be consistent with a traditional central bank view of the transmission mechanism. We have also shown that a significant role for nominal variables (whether interest rates or monetary aggregates) in indicator models of real output is consistent with their having no direct effect on it. Thus, evidence other than that summarized in indicator models seems to be necessary to distinguish between these structures.

In Section 3, projection properties are generated from a simulated model of intertemporal partial adjustment in the demand for money. In that DGP, some of the *qualitative* properties we seek to reproduce are built in directly; for example, the money-demand relation contains a lagged dependent variable arising from adjustment costs. Thus, we do not simply establish *qualitative* properties of the probability limits of the two projections, but instead, we begin to test DGPs more stringently by examining their *quantitative* properties. For example, we shall see whether this DGP can reproduce coefficient estimates or test statistics found in actual data.

3. Linear-Quadratic Money Demand

3.1 The data-generation process

So far, each DGP has been stationary. We turn next to a nonstationary and nonlinear (in parameters) structure and follow numerical methods. Note that the projection properties we now seek do not necessarily follow from the error-covariance restrictions found to be necessary in the previous section. We adopt simulation methods to control the complete probability distributions of the variables and to illustrate the use of recent numerical calibration techniques.

Here, we generalize the static money-demand functions of Section 2 by assuming that money holdings are set according to an intertemporal loss function with quadratic costs of adjustment. One may view these structures as realistic, as consequences of aggregation over money-holders, or as providing local linearizations of first-order conditions. Linear-quadratic problems are analyzed in Sargent (1987) and identification and estimation (under various exogeneity assumptions) with integrated variables are discussed by Gregory, Pagan and Smith (1990). Mercenier and Sekkat (1988) use the linear-quadratic framework to study an open-economy model in which the central bank sets the money supply or the nominal exchange rate. Domowitz and Hakkio (1990) find the intertemporal partial-adjustment mechanism successful in modelling money demand in several OECD countries.

The money-holder controls a scalar variable m (real balances), and faces the problem of minimizing the expected present value of adjustment and disequilibrium costs:

$$E_t \sum_{s=t}^{\infty} \beta^{s-t} \left[\omega(m_s - \theta x_s)^2 + (m_s - m_{s-1})^2\right] \tag{59}$$

where $\omega > 0$, and given m_t, a discount factor $\beta \in (0,1)$ and a law of motion for x_s. The vector x enters target money-holding; there are quadratic costs of adjusting money and of deviating from a balance of θx. For the analysis below, x is taken to be a scalar, while for the simulation results $x = (y\ r)'$, a vector. The parameter ω determines the relative size of the costs of adjustment. A first-order condition arising from equation (59) is:

$$E_t[\omega m_s - \theta\omega x_s + (1-L)m_s - \beta(1-L)m_{s+1}] = 0\,. \tag{60}$$

As is well known, both roots of the characteristic equation of this second-order difference equation are positive and real and lie on either side of one. Denote the roots λ_1 and λ_2 with $0 < \lambda_1 < \lambda_2$. A stability condition implies that $\lambda_1 < \beta^{-1/2}$ and leads to a solution of the form:

$$m_t = \lambda_1 m_{t-1} - (\lambda_1/\omega)\, E_t\, [\sum_{s=t}^{\infty} (\lambda_2)^{t-s}\theta x_s]\,. \tag{61}$$

The Wiener-Kolmogorov prediction formula can be used to replace the expectations (see Hansen and Sargent, 1981a) in equation (61) given a stochastic process for x. For simplicity, we shall assume that the law of motion for the forcing variable x is given by

$$\rho(L)x_t = \eta_t \tag{62}$$

where $\{\eta_t\}$ is an uncontrollable martingale difference sequence and roots of $\rho(L)$ are less than $1/\sqrt{\beta}$ in absolute value. Later on, we use a more specific example.

Example 1:

$$(1\text{-}L)(1\text{-}\rho L)x_t = \eta_t \tag{63}$$

with the parameter $|\rho| < 1$, so that the variables in x are integrated and their changes follow a first-order autoregression. Denote $\lambda = \lambda_1$ (i.e., the stable root). Equation (61) then becomes:

$$m_t = \lambda m_{t-1} + \theta(1\text{-}\lambda)(1\text{-}\rho\beta\lambda)^{-1}(1\text{-}\rho\beta\lambda L)x_t\ . \tag{64}$$

We use this formulation because it contains the following special cases:

(i) if $\beta = 0$, the standard partial-adjustment equation - i.e., $m_t = \lambda m_{t-1} + \theta\,(1\text{-}\lambda)x_t$;

(ii) if $\lambda = 0$ and x_t is suitably redefined, the case of instant adjustment to a permanent-income or present-discounted value-type measure;

(iii) an error-correction mechanism for money demand (see below and also Nickell, 1985).

Since results on error-correction representations are relevant to the papers by Ambler and Paquet and by Caramazza, Hostland and McPhail, also in this volume, we now digress briefly to consider circumstances under which the money-demand equation has an error-correction mechanism (ECM) form. First, suppose that $\rho(L) = (1\text{-}L)^d\rho'(L)$ where $\rho'(L)$ is of finite order with all roots of modulus less than one. Suppose that the econometrician knows d but does not know $\rho'(L)$. It is then straightforward to see that with this information set:

Example 2: d = 1

$$E(m_t \mid m_{t-1}, x_t) = \lambda m_{t-1} + \theta(1-\lambda)x_t \ .$$

Here, $\{m_t\}$ and $\{x_t\}$ are I(1), and $m_t = \lambda m_{t-1} + \theta(1-\lambda)x_t + \upsilon_t$, where υ_t is I(0) and an innovation with respect to the econometrician's information. In this example, $E_t(x_s)$ can be written as x_t plus a polynomial in the lag operator in terms of $(1-L)x_t$ and η_t. Thus, $E_t(x_s) = x_t$, $s \geq t$.

Example 2 involves very limited information, so that υ_t may exhibit considerable persistence. Nevertheless, consistent estimates of, say, θ may still exist. For example, the law of iterated expectations in Example 2 gives:

$$E_{t-1}(m_t) = m_{t-1} = \lambda m_{t-1} + \theta(1-\lambda)E_{t-1}(x_t)$$

so that

$$m_{t-1} = \theta x_{t-1} + \upsilon_{t-1} \tag{65}$$

where υ_{t-1} is an appropriate innovation. Equation (65) is a standard cointegrating regression with θ being the cointegrating coefficient. While OLS estimation of equation (65) yields a consistent estimate of θ, it may not be very efficient if λ is large (i.e., ω is small) so that $\{\upsilon_t\}$ is autocorrelated.

Consider also the case of I(2) variables.

Example 3: d = 2

$$E_t(m_t) = \lambda m_{t-1} + \theta(1-\lambda)(1-\beta\lambda)^{-1} (1-\beta\lambda L)x_t \ .$$

Here, $\{m_t\}$ and $\{x_t\}$ are I(2), and again $\upsilon_t = m_t - \lambda m_{t-1} - \theta(1-\lambda)(1-\beta\lambda)^{-1}(1-\beta\lambda L)x_t$ is an innovation for the econometrician. However, υ_t is I(1) in general; if this were fitted as an econometric equation (in standard partial-adjustment form for example), then the residuals could have a unit root.

Consider also a stationary case.

Example 4: stationary AR(1); $(1-\rho_1 L)x_t = \eta_t$

In this instance:

$$m_t = \lambda m_{t-1} + (1-\beta\lambda)(1-\lambda)\theta x_t/(1-\rho_1\lambda\beta)$$

is the solution to equation (61). This can be written as

$$\Delta m_t = (\lambda-1)(m_{t-1} - \theta x_{t-1}) + (1-\lambda)\,\theta\,[x_t(1-\beta\lambda)/(1-\rho_1\lambda\beta) - x_{t-1}]$$

or as

$$\Delta m_t = (\lambda-1)[m_{t-1} - (1-\beta\lambda)\theta x_{t-1}/(1-\rho_1\lambda\beta)] + (1-\lambda)(1-\beta\lambda)\theta\Delta x_t/(1-\rho_1\lambda\beta)\,.$$

This has an ECM form only if $\rho_1 = 1$.

Finally, we return to our original AR(2) (or ARIMA(1,1,0)) example. In Example 1, $(1-L)(1-\rho L)x_t = \eta_t$, equation (64) is

$$m_t = \lambda m_{t-1} + \theta(1-\lambda)(1-\rho\beta\lambda)^{-1}x_t - \lambda\rho\beta\theta(1-\lambda)(1-\rho\beta\lambda)^{-1}x_{t-1}\,.$$

To complete the DGP based on Example 1, we require the error term. If the target is $m^*_s = \theta x_s + \varepsilon_s$ then

$$E_t\,\omega\,(\beta\lambda_2)^{-1}\varepsilon_t/(-(\lambda_2 L)^{-1}+1) = \omega\lambda\varepsilon_t\,.$$

Thus, with the stochastic process for $\{x_t\}$ of Example 1:

$$\begin{aligned} m_t &= \lambda m_{t-1} + \theta(1-\lambda)(1-\rho\beta\lambda)^{-1}x_t \\ &\quad - \lambda\rho\beta\theta(1-\lambda)(1-\rho\beta\lambda)^{-1}x_{t-1} + \omega\lambda\varepsilon_t \,. \end{aligned} \tag{66}$$

To get the ECM in Example 1, subtract m_{t-1} from each side of (64). On the right-hand side, add and subtract: $\theta(1-\lambda)(1-\rho_2\beta\lambda)^{-1}x_{t-1}$. Thus

$$\Delta m_t = (\lambda-1)[m_{t-1} - \theta x_{t-1}] + \theta(1-\lambda)(1-\rho\beta\lambda)^{-1}\Delta x_t + \omega\lambda\varepsilon_t \,. \tag{67}$$

Note that the coefficient on Δx_t involves ρ and that Δx_t can be correlated with ε_t . In this case $\{x_t\}$ is AR(2) but the common factor induced by the integration allows us to write Δm_t in terms of the error-correction term and Δx_t alone. However, if we considered an example in which $\{x_t\}$ were a stationary AR(2) process, in general we could not write Δm_t in terms of a lagged error-correction term and a finite number of Δx_t's. Finally, OLS estimation of equation (66) is consistent only if: (i) $\rho = 0$ or (ii) Δx_t is weakly exogenous (i.e., the covariance between η_t and the error term in (66) is zero).

3.2 Simulation exercise

With this structure, we next simulate the DGP (Example 1, equation (66)) with specific parameter values. We then fit simple indicator models and standard money-demand models to the simulated data and calculate various Granger-causality tests. We allow $\mathrm{cov}(\varepsilon_t,\eta_t) \neq 0$, so that we do not assume that variables in x are exogenous.

In setting parameter values in the DGP, we calibrate the model to agree roughly with certain properties of the data. It is thus worthwhile to review briefly the data used and the correlation and regression results. Table 1 describes the data, while Table 2 gives the sample autocorrelation results.

Table 1
The Data

Variables	RM2, RI and R90
Periodicity	quarterly (not seasonally adjusted)
Time span	1968:02 - 1989:01 (84 observations)
RM2	currency and demand deposits net of private-sector payments in transit, all personal notice and fixed-term deposits and non-personal notice deposits at chartered banks, divided by the GDP deflator
RI	real income (1981 = 100)
R90	90-day prime corporate paper rate
LRM2 and LRI	RM2 and RI in logs
DR90	the first difference of R90
DLRM2 and DLRI	the first differences of LRM2 and LRI (i.e., growth rates)
DLRM2* and DLRI*	DLRM2 and DLRI seasonally adjusted by a constant plus three seasonal dummies
s.d.	indicates a constant and three seasonal dummies

In the notation used previously in Section 3.1, we identify $m_t = \text{LRM2}^*_t$ and $x_t = (\text{LRI}^*_t, \text{R90}_t)$. From Table 2 it is immediately obvious that LRM2, LRI and R90 are nonstationary and that there is a pronounced seasonal pattern for LRM2 and LRI. In Table 3 we try to remove the seasonal pattern by regressing these variables on a constant and three seasonal dummy variables (although clearly some stationary seasonality remains) to give DLRM2* and DLRI*.

Table 2
Sample Autocorrelations

	Level			First differences		
Variables	**LRM2**	**LRI**	**R90**	**DLRM2**	**DLRI**	**DR90**
r_1	0.9587	0.9326	0.9101	-0.2230	-0.0284	0.2003
r_2	0.9213	0.8711	0.7868	-0.1789	-0.8315	-0.0977
r_3	0.8857	0.8570	0.6817	-0.1752	-0.0598	-0.0436
r_4	0.8514	0.8410	0.5874	0.6002	0.9000	-0.0595
r_5	0.8145	0.7760	0.5056	-0.2670	-0.0290	-0.0552
r_6	0.7782	0.7174	0.4355	-0.1136	-0.7891	-0.0084
r_7	0.7398	0.7022	0.3665	-0.1529	-0.0559	-0.1553
r_8	0.7014	0.6870	0.3252	0.4400	0.8170	-0.0988
r_9	0.6615	0.6270	0.3010	-0.2307	-0.0029	0.0747
r_{10}	0.6237	0.5705	0.2602	-0.0367	-0.7305	0.0401
r_{11}	0.5890	0.5524	0.2084	-0.0676	-0.0522	0.0401
r_{12}	0.5518	0.5347	0.1555	0.2629	0.7527	-0.0202
⋮						
r_{24}	0.2009	0.1722	-0.0580	0.0475	0.5915	-0.0327
Variance	0.0766	0.0531	10.336	0.0004	0.0035	1.7336

If we return to the notation of equation (6[illegible]) in vector form, $\eta_t = \{\eta_{1t}, \eta_{2t}\}$ with $(1\text{-}L)(1\text{-}\rho_1 L)LRI^*_t = \eta_{1t}$ and $(1\text{-}L)(1\text{-}\rho_2 L)R90_t = \eta_{2t}$. For the simulation exercise, we set ρ_1 and ρ_2 equal to the first-order sample autocorrelations above: $\rho_1 = -0.427$ and $\rho_2 = 0.20$. Of course, there are alternatives to these simple ARIMA(1,1,0) models for income and interest rates. For example, one could simulate from a dynamic IS curve. Note also that the calibrated income and interest rate processes are not cointegrated; if they were, then there would be a singularity in static money-demand cointegrating regressions.

Table 3
Sample Autocorrelations with Seasonally Adjusted Data

Variables	DLRM2*	DLRI*
r_1	-0.1695	-0.4270
r_2	-0.2200	0.2825
r_3	-0.1028	-0.3752
r_4	0.5265	0.5492
r_5	-0.2145	-0.4585
r_6	-0.1629	0.2268
r_7	-0.0787	-0.2700
r_8	0.3458	0.3190
r_9	-0.1490	-0.2627
r_{10}	-0.1046	0.2528
r_{11}	0.0275	-0.2317
r_{12}	0.1312	0.0185
$\vdots$		
r_{24}	-0.1126	-0.0921
Variance	0.000316	0.000378

The variance-covariance matrix Vcov(ε_t,η_t} is obtained from the sample covariances for DLRM2*, DLRI* and DR90, as shown in Table 4.

Table 4
Covariance Matrix: Vcov(ε_t,η_t)

	DLRM2*	DLRI*	DR90
DLRM2*	0.00032		
DLRI*	0.00016	0.00038	
DR90	0.00371	0.00889	1.75445

Table 5
Estimated Regressions

Demand for money: Partial adjustment

$$\underset{}{LRM2_t} = \text{s.d.} + \underset{(0.0531)}{0.7728}\ LRM2_{t-1} + \underset{(0.0650)}{0.2711}\ LRI_t + \underset{(0.0015)}{0.0001}\ DR90_t$$

$$\bar{R}^2 = 0.9964 \quad D.W. = 2.0917 \quad Q(27) = 50.80$$

Demand for money: Long-run relation

$$LRM2_t = \text{s.d.} + \underset{(0.0156)}{1.2084}\ LRI_t - \underset{(0.0027)}{0.0070}\ DR90_t$$

$$\bar{R}^2 = 0.9864 \quad D.W. = 0.5741 \quad Q(27) = 258.483$$

Note: s.d. denotes seasonal dummy variables.

Simulations are obtained for ϵ_t and η_t by drawing T = 84 observations from a normal random-number generator with the variance-covariance matrix in Table 4. We calibrate the remaining part of the model from the money-demand projections shown in Table 5.

From the long-run relation in Table 5, we obtain the vector $\theta^T = \{\theta_1, \theta_2\}$ with $\theta_1 = 1.2$ and $\theta_2 = -0.007$. All that remains to complete the DGP is to set β and ω. We chose $\beta = 0.97$ (though results are not sensitive to this value) and set $\omega = 0.28$, which imply $\lambda = 0.6$ and an average estimated coefficient on $LRM2_{t-1}$ in a money-demand equation roughly equal to the above estimate of 0.77 (see the simulation results below).

So far, we have used the covariance matrix of growth rates (Table 4), the autocorrelation in growth rates (Table 3) and the money-demand projections (Table 5) to calibrate the model. Thus, we have assigned values to $Vcov(\epsilon_t, \eta_t)$, ρ_1, ρ_2, θ_1, θ_2, β, and ω. Since they are based on data, these values are econometric estimates. There is a well-developed theory concerning their properties (see Gregory and Smith, 1990 and Smith, 1989) although we have not been explicit about it here. Certainly, choosing the parameters to match certain properties of the data does not provide us with a test of the structure (although even this matching can be surprisingly difficult). Thus, we next provide such a test informally by comparing the indicator models using data simulated from the calibrated DGP with indicator models incorporating actual data. The comparison is quantitative, as it involves coefficient estimates and test statistics. The idea is simply that the parameters of the DGP are overidentified; the model restricts a wider range of phenomena than are necessary to estimate it. Gregory and Smith (1991) discuss formal inference using simulation methods.

The regression results shown in Table 6 are for vector autoregressions (VAR(2)) for the levels and first differences of money, income and interest rates. From these unrestricted regressions we calculate various Granger-causality tests.

From these VARs we calculate the simple Granger-causality tests shown in Table 7. For any three variables, let x, y and z denote (x, y) ngc z as the test under the null hypothesis that (x, y) do not Granger-cause z. Denote (x) ngc z(y) as the test of the null hypothesis that x does not Granger-cause z with y in the model.

These results indicate strong Granger-causality running from real income and interest rates to money in levels and first differences. On the other hand, the only other rejection of the null hypothesis of no Granger-causality occurs with money and interest rates jointly causing real income. However, if we control for interest rates, then money does not appear to have independent predictive power for income in this indicator model. It is well known that real M2 growth is not a particularly good indicator of subsequent real income growth, but again this fact of non-causality can provide a test of the calibrated DGP. Finally, there seems to be little evidence that either money or real income Granger-causes interest rates.

The question addressed in the simulation exercise is whether one can obtain Granger-causality results in the DGP similar to those obtained for the historical data in Table 7. We answer this question by simulating the model 1,000 times with $T = 84$ (the same number of observations used in the above regressions) for each replication, and by calculating the number of times we reject at the 5 per cent level of significance with each of the Granger tests in levels and first differences. High rejection frequencies suggest that this model is quite consistent with evidence in the data that finds Granger-causation. The entries in Table 8 indicate the proportion of rejections of the null hypothesis in 1,000 replications, with the same notation as for Table 7.

Table 6
Estimated VAR(2) Equations

Levels

$$
\begin{array}{lll}
LRM2_t = \text{s.d.} & +\ 0.82205\ LRM2_{t-1} & +\ 0.46836\ LRM2_{t-2} \\
 & \quad(0.1251) & \quad(0.12141) \\
 & -\ 0.11286\ LRI_{t-1} & +\ 0.32319\ LRI_{t-2} \\
 & \quad(0.12874) & \quad(0.12270) \\
 & +\ 0.00259\ R90_{t-1} & +\ 0.00191\ R90_{t-2} \\
 & \quad(0.00158) & \quad(0.00167)
\end{array}
$$

$\bar{R}^2 = 0.9959$ D.W. = 2.1706 Q(27) = 67.3101

$$
\begin{array}{lll}
LRI_t = \text{s.d.} & +\ 0.22761\ LRM2_{t-1} & -\ 0.13844\ LRM2_{t-2} \\
 & \quad(0.11600) & \quad(0.11254) \\
 & +\ 0.26032\ LRI_{t-1} & +\ 0.64564\ LRI_{t-2} \\
 & \quad(0.11934) & \quad(0.11374) \\
 & +\ 0.00087\ R90_{t-1} & -\ 0.00397\ R90_{t-2} \\
 & \quad(0.00147) & \quad(0.00155)
\end{array}
$$

$\bar{R}^2 = 0.9950$ D.W. = 2.0523 Q(27) = 36.5760

$$
\begin{array}{lll}
R90_t = \text{s.d.} & -\ 4.04702\ LRM2_{t-1} & +\ 4.62942\ LRM2_{t-2} \\
 & \quad(9.60909) & \quad(9.32293) \\
 & -\ 7.26430\ LRI_{t-1} & +\ 7.71878\ LRI_{t-2} \\
 & \quad(9.88637) & \quad(9.42198) \\
 & +\ 1.17617\ R90_{t-1} & -\ 0.33541\ R90_{t-2} \\
 & \quad(0.12146) & \quad(0.12807)
\end{array}
$$

$\bar{R}^2 = 0.8390$ D.W. = 1.9451 Q(27) = 19.1547

(cont'd)

Table 6 (cont'd)
Estimated VAR(2) Equations

First difference

$$
\begin{aligned}
DLRM2_t = \text{s.d.} \quad & \underset{(0.1229)}{-\ 0.07920\ DLRM2_{t-1}} && \underset{(0.12332)}{-\ 0.25282\ DLRM2_{t-2}} \\
& \underset{(0.13390)}{-\ 0.23229\ DLRI_{t-1}} && \underset{(0.13670)}{-\ 0.08308\ DLRI_{t-2}} \\
& \underset{(0.00163)}{-\ 0.00191\ DR90_{t-1}} && \underset{(0.00160)}{+\ 0.00264\ DR90_{t-2}}
\end{aligned}
$$

$\bar{R}^2 = 0.2656$ D.W. = 2.1104 Q(27) = 38.95

$$
\begin{aligned}
DLRI_t = \text{s.d.} \quad & \underset{(0.1273)}{+\ 0.17145\ DLRM2_{t-1}} && \underset{(0.12817)}{-\ 0.15517\ DLRM2_{t-2}} \\
& \underset{(0.13917)}{-\ 0.47857\ DLRI_{t-1}} && \underset{(0.14208)}{+\ 0.20469\ DLRI_{t-2}} \\
& \underset{(0.00169)}{+\ 0.00096\ DR90_{t-1}} && \underset{(0.00166)}{-\ 0.00053\ DR90_{t-2}}
\end{aligned}
$$

$\bar{R}^2 = 0.9090$ D.W. = 1.9313 Q(27) = 28.73

$$
\begin{aligned}
DR90_t = \text{s.d.} \quad & \underset{(9.61135)}{-\,6.38895\ DLRM2_{t-1}} && \underset{(9.64445)}{-\,4.62959\ DLRM2_{t-2}} \\
& \underset{(10.4721)}{+\ 5.91589\ DLRI_{t-1}} && \underset{(10.6907)}{+18.38602\ DLRI_{t-2}} \\
& \underset{(0.12753)}{+\ 0.22935\ DR90_{t-1}} && \underset{(0.12500)}{-\ 0.22207\ DR90_{t-2}}
\end{aligned}
$$

$\bar{R}^2 = 0.0151$ D.W. = 1.9794 Q(27) = 18.57

Table 7
Granger-Causality Tests

	Likelihood-ratio statistics (significance levels)	
	Levels	Differences
(LRI, R90) ngc LRM2	19.5041 (0.00062)	11.4438 (0.022)
(LRM2, R90) ngc LRI	32.4530 (0.00000)	7.0116 (0.14)
(LRM2) ngc LRI (R90)	5.1447 (0.76)	4.17 (0.12)
(LRM2, LRI) ngc R90	4.4313 (0.35)	5.3968 (0.067)

Table 8
Granger-Causality Tests in an Artificial Economy

	Rejection frequency	
	Levels	Differences
(LRI, R90) ngc LRM2	0.686	0.321
(LRM2, R90) ngc LRI	0.103	0.065
(LRM2) ngc LRI (R90)	0.060	0.039
(LRM2, LRI) ngc R90	0.110	0.057

Table 8 gives the properties of some simulated indicator models. We also construct standard money-demand projections (in levels) in the simulated data. For the 1,000 replications, the average coefficient estimates for the partial-adjustment money-demand equation are 0.80, 0.22 and -0.0012, for lagged money, real income and interest rates, respectively. The average long-run money-demand coefficients for income and interest rates are 1.12 and -0.0066, respectively. Both of these are similar to the earlier regression results shown in Table 5. However, it should be kept in mind that the estimate of λ by ordinary least squares from a levels equation in a partial-adjustment model is not consistent (recall $\lambda = 0.6$ and the implied average estimate is $\hat{\lambda} = 0.8$). Since money is cointegrated with income and interest rates, such a regression has an asymptotic singularity and so the partial-adjustment regression in levels is not well defined. Consistent procedures for estimation that lead to valid inferences are discussed in Gregory, Pagan and Smith (1990).

Broadly speaking, the results from the simulation exercise compare quite favourably with the empirical test results on actual data. The model delivers strong Granger-causation (both in levels and first differences) from income and interest rates to money. The lower rejection frequencies for the null hypothesis of no Granger-causation for income (both with and without controlling for the interest rate effect) and interest rates also appear to be consistent with the results from the data.

This same Monte Carlo laboratory could be used to study further issues in the estimation of money-demand projections such as inferences about adjustment speeds or elasticities. Likewise, changes in the interest rate process could be introduced and the effects of these regime changes on the stability of indicator-model and money-demand projections traced.

4. Extensions

In this paper, we have studied some simple, linear economic models to examine the relationships between money-demand and indicator-model projections. Two deficiencies of our study should be mentioned here. First, we have not referred directly to much statistical evidence on interest rates and inflation and the causes of their variation. The DGP in the previous section does not address the adjustment of nominal money balances to inflation or the role of M2 growth as an indicator of subsequent inflation. Nor have we studied facts related to the behaviour of the nominal exchange rate. We have also not synthesized indicator models with existing empirical models of aggregate supply.

Second, we have not adopted a data-generation process explicitly based on optimization. This task is difficult and there is no widespread agreement on how to model money in equilibrium macroeconomic models. A selection of background reading with which to begin might include: LeRoy (1984a, 1984b) on money in the utility function, Blanchard (1987) on money in the utility function and menu costs under monopolistic competition; Romer (1986, 1987) on models based on transactions costs, and Englund and Svensson (1988) on transactions costs (cash in advance) with banks and financial innovation.

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Commentary

by Peter Howitt

This is a finely crafted paper that deals honestly and intelligently with the three main questions put to the authors. If in the end the paper is disappointing, it is mainly because the questions were too easy.

The first question was whether it is possible to reconcile the evidence from indicator models - that money leads output - with the evidence from money-demand models that output (income) leads money. I thought every graduate student knew the answer to that one - that the relationship of Granger-causality can be reflexive, that one variable can both precede and be preceded by another in a vector autoregression.

In the case of the two variables in question here, the money-demand literature provides many reasons why income should precede money, including costs of adjustment, measurement error, permanent income, buffer stocks, and so on. It is obvious that any shock that simultaneously shifts aggregate demand and the supply of money will make money lead income, even controlling for interest rates, provided only that changes in aggregate demand take time to affect output.

Examples of this kind of shock include changes in the demand for credit from either the public or the private sector. This mechanism has been familiar at least since Keynes's discussion of the "demand for finance." Likewise, a reduction in the cost of credit intermediation, to borrow Bernanke's phrase, could lead to an expansion of bank assets and liabilities before the induced increase in spending shows up in final output. The same applies to the consolidation of balance sheets that the Bank of Canada believes to be the cause of the 1983 shift in M2 velocity, provided that the consolidation was associated with a reduction in planned spending.

The second question was whether these results are consistent with "traditional views of the monetary transmission mechanism," which I assume is textbook IS-LM analysis with the rate of interest as the instrument of monetary policy. Again, it takes little more than a passing acquaintance with modern macroeconometric literature to know that the answer is "yes." Granger-causality results may or may not be useful as a means of presenting data, but they do not by themselves imply anything about the structure of the economy or about causal connections in any economically interesting sense. A given set of results will be consistent with almost any broad view of the functioning of the economy.

The final question was what the econometric results suggest about the transmission mechanism and the structure of the economy if they are not consistent with traditional views. Since they are in fact consistent with traditional views, the answer is anything you want it to be, on the grounds that any conclusion can be drawn from a contradictory set of premises.

Fortunately, the authors go beyond these questions, and there is a lot to be learned from their analysis. For example, they ask what is implied about the nature of aggregate shocks by the signs of coefficients, assuming the traditional view is correct. In particular, lagged money typically has a positive effect on income and lagged income a positive effect on money. The authors show that this implies that the IS shock is positively correlated with the lagged money shock and negatively correlated with the contemporaneous money shock. The former is necessary for lagged money to have a positive effect on income and the latter to get lagged income to have a positive effect on money.

At this point I have a slight quibble with the paper. The requirement that the IS shock have a positive correlation with the lagged money shock but a negative correlation with the contemporaneous one, seems stringent enough to rule out a lot of potential models, and perhaps also unlikely enough to cast doubt on the traditional view. But that stringent requirement is, to a large extent, a result of the very narrow interpretation the authors have given to the traditional view rather than the difficulty of squaring that view with the evidence.

In particular, their "traditional view" includes a money-demand function with no lags in it. If instead we took any of the standard reasons to include lagged income in the money-demand function, then a negative contemporaneous correlation between the IS and money shocks would no longer be needed to get income to lead money. Instead, the lead would be built right into the structure of the model. Under this alternative interpretation, all the data are telling us is that the IS shock is positively correlated with the lagged money shock. And, as I have argued, there is no shortage of reasons why this might be the case.

In fact, this is what the authors do when they simulate a model based on a money-demand function with an adjustment cost. The only difference is that instead of using an IS curve, they suppose that output and the rate of interest follow exogenous stochastic processes. They show that econometric estimation of money-demand functions and indicator equations performed on data generated by a calibrated version of this theoretical model would look much like the estimations performed on actual Canadian data. Clearly, one important reason for this success is that they have assumed a positive correlation between the output innovation and the money-demand shock. Since the exogenous output process has positive autocorrelation, this also implies a positive correlation between the output shock and the lagged money shock. Thus, they are assuming what I have argued we already know the data are telling us.

This simulation exercise illustrates an innovative and potentially useful technique. However, the technique has important drawbacks that are well known from the related work of Kydland and Prescott. In particular, there is no end to the number of different models that can reproduce a given small set of observations perfectly with judicious choices during calibration. And the analysis yields no confidence intervals. Should I be surprised that the model reproduces actual econometric results as well as it does, or surprised at how poorly it does? Until this question is dealt with systematically, simulations like those in this paper will remain interesting exercises with no empirical implications.

I would like to conclude by noting what I think is the most important implication of the earlier part of the paper. The Bank of Canada has, in the past, often taken the view that a large negative error in forecasting money should not be resisted; that the decline in money should be permitted to take place with no necessary change in interest rates. That was an important part of the Bank's rationale for using the interest rate as the instrument of control under gradualism in the 1970s. The same argument was invoked in the Bank's interpretation of the velocity shift of 1983, which it interpreted as justifying the continuation of monetary deceleration in the face of extraordinarily high unemployment.

The paper shows that under the traditional view of the monetary mechanism, to which the Bank has in the past subscribed, this reaction to a money shock is normally wrong. Usually, a negative money shock signals a negative output (IS) shock. Thus, unless there is strong evidence of an exceptional case, the Bank's reaction to a large negative money shock should be to try to keep the money supply on track: to prevent the shock from persisting and thus reinforcing the economic downturn likely to follow.

Commentary

by Pierre Duguay

After such an elogious review by Professor Howitt, I feel I have to defend the question before I can comment on the answer offered by Gregory, Smith and Wirjanto (GSW). I intended to do so, anyway, for I find that the authors strayed somewhat from the practical concerns that underlay the question: "Does the evidence from astructural indicator models reveal something about misspecification, measurement error or the transmission mechanism of monetary policy?" GSW present an elegant taxonomic restatement of the problem, an essential step to clear thinking about the question, but do not provide very concrete answers.

Professor Howitt finds the question too easy, perhaps uninteresting, commenting: " ... the answer is anything you want it to be, on the grounds that any conclusion can be drawn from a contradictory set of premises." Yet he does conclude in the end that, based on the evidence from astructural indicator models, the Bank's view of shifts in money demand as a movement to be accommodated is normally wrong. But I would say that if the Bank is to change its view, it needs to understand why.

Let us look at the problem from a central banker's perspective. Central banks are aware that their actions have a fairly *direct* influence on the day-to-day movements of the very short-term interest rates and a very *indirect* influence on the trends in monetary aggregates. The central banker also knows that in the longer run, monetary policy cannot control interest rates but must contain the rate of monetary expansion in order to ensure that money retains its value, thus contributing to the fullest extent to lasting good economic performance.

In 1975, we thought that we could resolve that dilemma by targeting on M1. The demand for M1 being quite sensitive to variations in interest rates and in total spending, it could be used to help regulate total spending much the same way a thermostat is used to regulate the temperature. (It had been observed that large swings in M1 tended to precede similar swings in total spending. These large swings could be avoided by setting interest rates so as to keep M1 on a steady growth path.)

But M1 abandoned us. The thermostat could not control for unpredictable changes in atmospheric pressure. Twenty years of reasonable stability in the relationship between M1, GNP and interest rates came to an end in 1980. The demand for M1 was so sensitive to interest rate variations anyway, that targeting on M1 tended to dampen excessively the reaction of interest rates to changes in spending, thus causing, in the end, overshooting in both interest rates and spending (vividly illustrated by the 1981-82 recession). In other words, regulation of M1 was too easy a task, and gave too much leeway to spending.

So the search for the Holy Grail continued. Not surprisingly, our search led us to the broader aggregates, which are less influenced by the general trend in interest rates and which internalize the many shifts that result from financial innovations. It had already been observed that while M1 growth was decelerating from 1975 to 1981, growth in the broader aggregates accelerated along with total spending. (Indeed, one stylized fact of Canada's monetary experience in the last two decades is the presence of some negative correlation between M1 and M2 growth at business cycle frequencies, as shown in the accompanying chart.)

Yet we remained sceptical because we had no *a priori* reason to expect a strong relationship between the broader aggregates and total spending, and many reasons to suspect the relationship to be excessively sensitive to portfolio shifts brought about by shifts in patterns of credit demand. Nonetheless, the econometric evidence turned out to be quite favourable to the broader aggregates, particularly M2 and M2+. M2 emerged as the best leading indicator of inflation (CPI or GDP deflator), M2+ was among the best contemporaneous indicators of total spending, and the demand for M2 and M2+ could be described with reasonable accuracy (albeit in growth rates rather than in levels) in terms of a few arguments. However, real M1 growth remains the best leading indicator of real spending growth in spite of, or even abstracting from, the large shifts that the demand for that aggregate underwent in the early 1980s.

Still, the econometric evidence has not provided the "place to stand" that Governor Bouey was seeking.

Now that we have this information, the problem is what are we to do with it? The Bank has only a limited, indirect influence on M2 and M2+ growth, and that influence is at least as loose, if not looser, than its effect on total spending. Thus, there can be no question of using M2 and M2+ as intermediate targets the way we did with M1. With M1, there was a strong presumption (until 1981) that deviations from targets resulted from deviations of total spending from its projected path. With M2 and M2+, the case is less clear. On the one hand, indicator models tell us that M2 and M2+ are contemporaneously correlated with spending, and provide a leading indicator of prices. On the other hand, the estimated demand functions for M2 and M2+ confirm our priors that current spending has a limited contemporaneous effect on these aggregates and that other extraneous factors, such as changes in interest rate differentials and swings in CSBs, can exert profound influences on M2 and M2+ growth.

How are we to reconcile these two views? Should we worry that rapid M2 growth is a harbinger of higher inflation if we can attribute it to a weak CSB campaign or to shifts in the banks' share of the deposit market? (Let me note in passing that M2 performs distinctly better than M2 adjusted for CSBs in the indicator model for prices and marginally better than M2+, although M2+ is a better coincident indicator of nominal spending.) How do we interpret M2 growth at a faster (or slower) pace than our monitoring equation predicts? These are very practical questions, and it does not help much to know what steady-state rate of inflation is consistent with a given sustained pace of M2 growth, when the object is to gauge the implications of current M2 growth for policy. Some reconciliation, in particular some structural interpretation of the results, is necessary for the Bank to feel comfortable with the information it can extract from its indicator models. This is particularly the case when other indicators or private and public forecasts point the other way.

The way we put it to the participants at this conference was: "Are indicator-model results consistent with the traditional central bank view of the transmission mechanism, or do they raise questions about our modelling of the transmission process and of the demand for money?"

The traditional view is that the quantity of money is primarily demand-determined and that the effect of monetary policy is channelled through prices (i.e., interest rates) rather than through quantity. It can explain the stylized facts that M1 leads real income (by some two quarters), M2 lags real and nominal spending (by about one quarter) but leads prices (by two quarters or more), simply in terms of the lags from interest rates to aggregate demand and from aggregate demand to prices. Contemporaneous correlation between money and spending is also easily interpreted. If that's all there were to it, the aggregates might not bear a lot of watching. Of course, the position of M2 as lagging nominal spending by one quarter (roughly, the publication lag of the National Income and Expenditure Accounts) but leading prices can help fend off calls for premature easing. While this is not an immaterial benefit, it is nothing to get too excited about. But it can make writing an article on the behaviour of monetary aggregates in a year like 1989, when M2 growth rose to 13 per cent and total spending was distinctly heading down, rather challenging.

However, the empirical evidence goes somewhat beyond that. We also find lingering, lagged effects of M1 on spending after the effects of lagged interest rates and lagged spending are accounted for, and lingering, lagged effects of M2 growth on inflation after the effects of lagged inflation and lagged spending are accounted for. (This point is not emphasized by Patrice Muller, who focussed on parsimonious models, but it is an important feature of astructural indicator models - as can be seen, for example, in the appendix at the end of my comments.)

Of course, one should never underestimate the inventiveness of economists in finding omitted variables in the simplistic IS/LM framework (or in the indicator model) that will square with the facts.[1] More importantly, it must be remembered that one cannot identify the structure of the economy from a VAR or any reduced-form model. And, indeed, GSW remind us of this. They cover a broad spectrum of explanations, from misspecification (i.e., omitted variables) to spurious correlation, and warn that the presence of money in indicator models can be consistent with both the traditional central bank view of the transmission process and with the real business cycle view that nominal variables have no direct effect on real output. Some demonstrations appear a bit self-indulgent (e.g., equations (7) to (8) in GSW) or far-fetched (equations (53) to (58)), but they do make their point. GSW are the first to admit that some of their results are truisms rather than explanations.

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[1] Obvious candidates are wealth effects and credit market behaviour. But wealth effects are notoriously difficult to identify, and credit variables tend to lag rather than lead real spending. In addition, the results that Allan Crawford presented at this seminar indicate that the information content of real M1 for real spending is not diminished when consumer credit - which is most tightly related to spending - is included in the information set.

The most interesting of the arguments put forward by GSW is the demonstration that income-measurement errors can account for both the estimated lag in the effect of income on money (as already demonstrated by Goodfriend) and the information content of lagged money (in addition to lagged income) in explaining spending. The illustration of the practical importance of this argument would have been more useful, however, if the relative variances of η, ε and $\tilde{\omega}$ had been chosen to correspond to the Canadian reality. One could apply the same argument to the presence of lagged M2 growth in the astructural indicator model of inflation: because price changes reflect transitory disturbances, a (linear) combination of lagged M2 growth and lagged inflation may be helpful in defining core (expected) inflation.

That the presence of errors in the measurement of income may explain some of the observed results is supported by the work of Patrice Muller who showed, for instance, that the indicator models tended to anticipate national accounts revisions.

I was disappointed by the last section of the GSW paper. Here, the authors attempt to draw some empirical evidence from simulation testing. But, as is the rule with simulation exercises, their value depends very much on the structure of the underlying model, and in this case the chosen structure is not very helpful. GSW take us through a relatively complex dynamic optimization model of the demand for real balances only to yield a simple partial-adjustment model. They then perform Monte Carlo simulations to show that OLS estimates tend to understate the true speed of adjustment of money balances, but otherwise capture fairly well the causal relationship in an artificial economy where income and interest rates, the two explanatory variables of the demand-for-money function, follow simple ARIMA(1,1, 0) data-generating functions.[2] This model, calibrated for real M2, is not liable to shed much light on either the role of real M1 as a leading indicator of real output or that of M2 growth as a leading indicator of inflation. GSW point towards the promises that the use of numerical methods based on statistics calculated from artificially generated data offer as an alternative means of estimating model parameters - and presumably testing economic hypotheses - but in the end they do not really explore them.

Appendix

The regression results presented in the accompanying table show that changes in interest rates have little influence on spending growth beyond that channelled through real M1 growth, and that other influences on real M1 growth have the same effect on real output as those arising from changes in interest rates.

Equations (1) and (2) in the appendix table show that changes in (nominal) interest rates (Δr) have a significant influence on the growth rates of both output and real M1 and that the influence on the latter is both more rapid and more pronounced. (The effect on velocity can be seen in equation (3).) Equations (4) and (5) show that the influence of real M1 growth on real spending captures most of the effect of interest rate changes (i.e., the latter are no longer significant, except maybe for a small residual effect after five quarters) and adds considerable explanatory power to the equation (the $\bar{R}^2$ rises from 0.17 to 0.28).

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[2] There is evidence from the strong seasonal pattern in the correlogram of GSW's "deseasonalized" GDP growth rates (Table 3) that real income is not modelled effectively by a simple ARIMA (1,1,0) process. GSW might have been better served by the official seasonally adjusted GDP. The preference of time-series analysts for raw data continues to escape me.

Finally, equation (6), in which the rate of growth of real M1 (Δm), is split between its fitted ($\Delta\hat{m} = \hat{A}_0 + \hat{A}(L)\ \Delta r$) and residual ($\Delta m - \Delta\hat{m}$) components, confirms that both components exert a similar influence on real income growth (Δy).

Figure A.1

Four-Quarter Growth Rates: M1 and M2

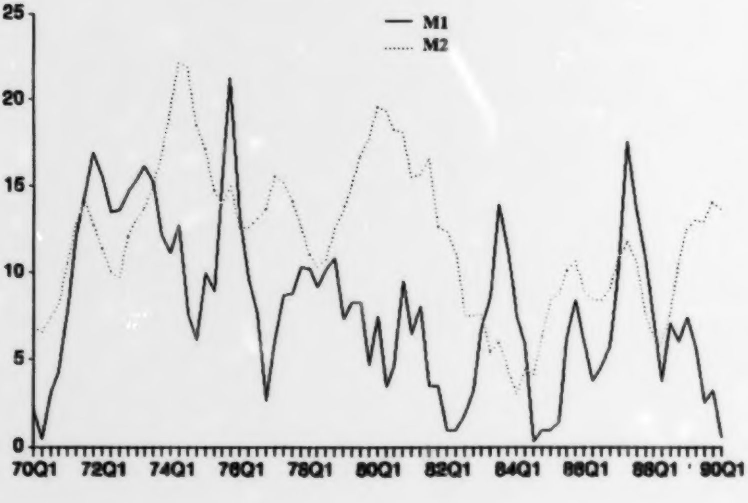


Table A.1
Regression Results for Real M1 and Real GDP
(Sample period: 1970Q1-1990Q1)

Equations:

(1) $\Delta y = A_0 + A(L)\Delta r$
(2) $\Delta m = A_0 + A(L)\Delta r$
(3) $(\Delta m - \Delta y) = A_0 + A(L)\Delta r$
(4) $\Delta y = A_0 + A(L)\Delta r + B(L)\Delta m$
(5) $\Delta y = A_0 + B(L)\Delta m$
(6) $\Delta y = A_0 + B(L)\Delta \hat{m} + C(L)(\Delta m - \Delta \hat{m})$

y: log (real GDP)
m: log (real M1)
r: 90-day commercial paper rate (%/100)

Regression results: (t-tests in brackets under the coefficients)

	(1)	(2)	(3)	(4)	(5)	(6)
A_0	0.97E-2	0.34E-2	-0.63E-2	0.86E-2	0.85E-2	0.86E-2
	(9.67)	(2.00)	(-3.67)	(8.84)	(9.28)	(9.17)
A_1	0	-0.87	-0.88	-0.06		
	(0.05)	(-6.49)	(-6.53)	(-0.76)		
A_2	-0.11	-0.26	-0.15	0.03		
	(-1.41)	(-1.91)	(-1.09)	(0.34)		
A_3	-0.20	-0.29	-0.09	-0.02		
	(-2.47)	(-2.12)	(-0.66)	(-0.20)		
A_4	-0.07	-0.34	-0.27	0.02		
	(-0.92)	(-2.47)	(-1.94)	(0.20)		
A_5	-0.22	-0.09	0.13	-0.13		
	(-2.76)	(-0.68)	(0.94)	(-1.60)		
A_6	-0.11	-0.14	-0.03	-0.05		
	(-1.41)	(-1.01)	(-0.18)	(-0.62)		
A_7	-0.04	-0.16	-0.12	-0.01		
	(-0.49)	(-1.17)	(-0.89)	(-0.06)		
A_8	-0.06	-0.06	0	-0.01		
	(-0.70)	(-0.43)	(-0.02)	(-0.16)		
A(1)	-0.81	-2.21	-1.40	-0.22		
mean lag: $\sum iAi/\sum Ai$	4.46	2.94	2.06			
B_1				0.16	0.17	0.15
				(2.43)	(3.48)	(1.94)
B_2				0.17	0.18	0.22
				(2.58)	(3.89)	(2.92)
C_1						0.16
						(2.55)
C_2						0.15
						(2.38)
$\bar{R}^2$	0.17	0.43	0.38	0.28	0.32	0.31
S.E.E.	0.93E-2	1.54E-2	1.53E-2	0.83E-2	0.81E-2	0.81E-2
D.W.	1.65	1.82	2.23	1.97	2.00	1.94

General Discussion

Charles Freedman asked if the indicator models were really more stable than the money-demand functions, or if this reflected the fact that we have been comparing growth-rate equations for the indicator models with our experience with level equations for money demand (in the case of M1 at least). Kim McPhail replied that, as Pierre Fortin had suggested the previous day, the fact that indicator models have less predictive power than money-demand functions means that the stability tests for the indicators are less powerful. Patrice Muller said that M1 in a growth-rate specification would have larger standard deviations and forecast errors over the post-1979 period than over the 1970s. The fact he found more interesting was that the indicator models' forecast standard deviations were greater than their estimation standard deviations.

Jack Selody agreed with Peter Howitt that, for policy analysis, the authorities cannot ignore innovations in money. He felt that if money-demand functions only predict money, the Bank could look at the results or ignore them, but the indicator models purport to predict *income*, which is a target variable, and therefore should require a response. He asked Howitt if he thought the paper by Smith et al. had anything to contribute? Howitt thought not, as the stability tests with the indicator model were too weak and the models were, in any event, subject to the Lucas critique. Otherwise, he felt the indicator-model results would need to be taken into account. Patrice Muller added that the relative stability of the indicators may in part reflect the fact that they have not been used for policy purposes. This stability might disappear if the Bank began to use them actively. Pierre Duguay said he was less negative on the indicator models. As they provided only one-quarter-ahead forecasts they may not in fact be very sensitive to the policy regime.

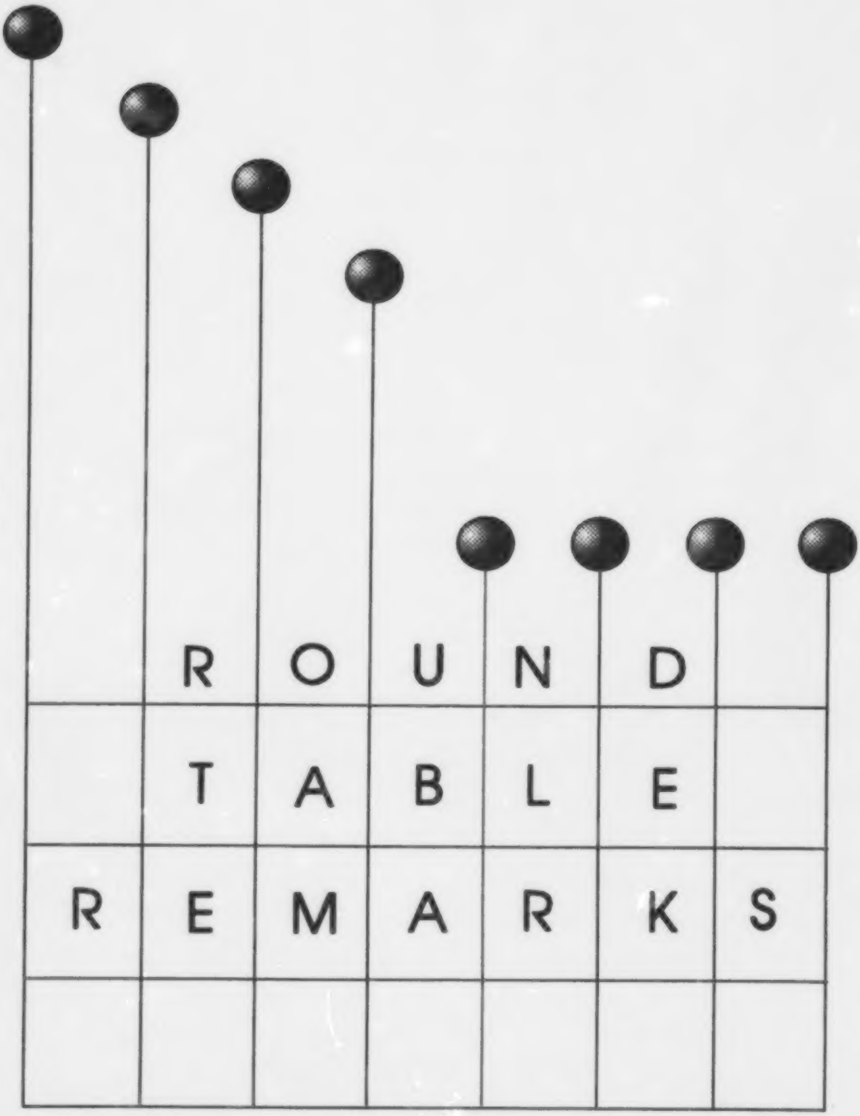
Kim McPhail found the various hypotheses in the Smith et al. paper (i.e., exogenous interest rates, exogenous money, etc.) useful as they could suggest the probable direction of bias of some coefficient estimates in the Bank's models. She felt that deriving money-demand functions that distinguished between the cases where variables were I(0) and those where they were I(1), was helpful, since our structural partial-adjustment models date from the period when this issue was not considered (i.e., when all the variables were implicitly assumed to be stationary).

Alain Paquet was less confident (than some) that the indicator models were useful for policy purposes. In particular, he thought that the problem of defining the logic of the links between variables when they are seen to be correlated was underestimated. He liked the paper's efforts at tackling this problem.

Charles Freedman asked what economic interpretation should be attached to the two key correlation coefficients that produce the results. Gregor Smith replied that he was agnostic on the issue but that the first result can be attributed to measurement error.

Duguay commented that much of the empirical work had focussed on real M2 and real income, and that the fact that the VAR gave no results was not surprising as real M2 had tended to be flat with M2 leading prices, not real income. He asked for the intuition behind the result in the paper's last section that the speed of adjustment was overestimated.

In his final rejoinders, Smith accepted the criticism that the data-generating processes in Sections 2 and 3 were not sufficiently economically motivated. He thought that their supply-side representations could be improved. He felt that it was a good idea to look further at the relative stability of the two kinds of models, and to try to use instability tests for identification. He added that while he found measurement error to be the most interesting case, it was not the whole story. The scale of the error is important. The overestimation of the speed of adjustment arises because the forward-looking smoothing in their models, which is AR2, is not exactly the same as the permanent-income hypothesis.



ROUND TABLE REMARKS

ROUND TABLE REMARKS

by Peter Howitt

The dynamics of the demand for money

As at most conferences, our discussion has tended to focus on those matters on which there is disagreement. This is the way it should be, of course, since our time together would not have been spent efficiently if much of it had been devoted to matters that were already settled. It is important, however, to keep disagreements and controversies in perspective by recalling that not only are there many issues on which we agree, but also that a lot of the disagreements concern issues which, from a practical point of view, are of secondary importance.

In particular, it is important to recognize that the properties of the money-demand function that we have been discussing are mostly short-run dynamic properties. There seems to be little disagreement about the long-run steady-state properties. Some equations imply different long-run income elasticities and different amounts of long-run drift. But from the point of view of a monetary policy aimed at a long-run inflation target - zero or otherwise - all that matters is the overall trend in the amount of real money demanded. How much of that overall trend comes from growth of real income feeding through the income elasticity, instead of through drift in the demand function itself, is of little practical importance. My impression is that the various estimated demand equations for M2 do not differ significantly in the size of their overall trends, just in the amounts attributable to different components.

Much of the disagreement about short-run dynamic properties is also of little practical significance. How much difference does it really make, for example, whether the money-demand function is expressed in first differences or whether it is expressed in levels, but with very long lags? In the former case, shocks have a permanent effect on the demand for money, whereas in the latter they will eventually go away; but if "eventually" means a decade or more, then the difference between the two points of view is more formal than substantive.

Ambler and Paquet present a third alternative in which the residual in the demand-for-money function has no unit root (as it would in the money-demand equations expressed as first differences) but there is a single large permanent shock in January 1983. This looks to me like the unit root case. One could think of the residual as having both permanent and transitory components, as Jean-Marie Dufour suggested in some of his commentary during the conference. If the transitory component followed a Poisson process with a large probability of coming up zero each period, it would be likely to produce the kind of evidence that Ambler and Paquet interpret as a stationary process with one permanent break. What practical difference would it make whether this or the random-walk model applied? It would be useful for someone to work out the implication of having both permanent and transitory shocks, and of having the permanent shocks be in frequent Poisson arrivals rather than in smoothly distributed increments.

While on the subject of unit roots I feel compelled to raise the spectre of nonlinearities. Nonlinear dynamics are so hard to work with, even without stochastic disturbances, that the econometrician's urge to avoid them is understandable. But if we maintain the likelihood of unit roots, then we must deal with the following implications. Either the world is exactly linear, or else our linear models are just an approximation to reality. In the former case, one has to be very suspicious of unit roots, since models with roots that are close to, but not equal to unity in absolute value have different asymptotic properties, and it seems unlikely that the economy has picked the unity needle from the haystack of all possibilities. In the latter case, one has to realize that nonlinear systems whose linear approximations have a unit root at a steady-state equilibrium also tend to have bifurcations at those equilibria, and hence tend to behave quite differently from their linear approximations - which in fact are bad approximations in that instance. In either case, evidence of unit roots is evidence that the linear model being used is not reliable. I have no constructive solution to this dilemma, but I think one has to keep it in mind when judging the significance of econometric exercises of the sort we have seen at this conference.

Theory and measurement

This conference has been very econometrics-intensive. This is entirely appropriate, given that the issues we have been discussing concern the quantitative interpretation of econometric results. There is another related feature of the conference that must be noted, however, which is less than appropriate. That is, while the econometrics that have been used in the various papers include some of the most up-to-date techniques, the underlying economic theory is vintage 1944. The papers are all organized around IS-LM analysis. With the exception of the Gregory-Smith-Wirjanto paper, they contain no microfoundations and ignore the possible implications of rational expectations. It seems to me that we need to do more theoretical work in order to progress with some of the issues we have been discussing, and to do that we have to consider a broader range of theoretical frameworks than these papers have used.

The Bayesian vector-autoregressions of Racette and Raynauld, for example, strike me as an extremely useful way of organizing the data. I think this econometric method is going to be used more and more. But we have to resist the temptation to read anything of causal significance into the results. Without a fairly detailed specification of a theoretical framework, the results by themselves have no substantive implications whatsoever.

With respect to the main substantive issue of the conference - the interpretation of the predictive content of money as an indicator with respect to real and nominal income and prices - I think we have reached the point where no more progress can be made without a heavy investment in building a theoretical framework that will accommodate the main hypotheses that have been advanced. In particular, this seems to me to call for more research on the money-supply process in Canada. The thing we call a money-demand equation is at best a reduced-form relationship that summarizes, among other things, the portfolio choices of the public, the reaction function of the Bank of Canada and the lending and deposit-creating behaviour of the chartered banks. We need to be more explicit about the interrelationships among these activities before we can get a good empirical handle on the issue.

Consider, for example, the shift in M2 velocity that appears to have occurred sometime around 1983. The Bank's favourite interpretation is that the shift reflected a balance sheet consolidation on the part of the public, the kind of event that could be represented by a shift in the LM curve with no shift in the IS curve. This interpretation focusses exclusively on the public's portfolio behaviour with no reference to either central bank policy or chartered bank behaviour, and it leads to the policy conclusion that the shift should have been accommodated by a reduced rate of monetary expansion.

Even if one buys the balance sheet consolidation interpretation, however, it is possible that the chartered banks (and other intermediaries) did not play a passive role in the process. One interpretation is that the consolidation was the public's reaction to an increased unwillingness on the part of intermediaries to accommodate the demand for credit. This unwillingness would naturally induce people to consolidate their balance sheets in order to attain a more liquid position. As well as causing an LM shift, however, it would also cause an IS shift, since the decreased availability of credit would reduce the effective demand for output. This interpretation also suggests that the appropriate policy response was not to reduce the rate of monetary expansion but to keep money on track, allowing a latent excess supply of money to counteract the contractionary real effects of the shock.

It is not obvious to me how one could make a definite judgment as to which of these interpretations is closest to the truth. Under the latter interpretation, if the decreased willingness of lenders to extend credit took the form of a change in the non-interest terms offered by lenders, or in the criteria used in assessing risks, then it need not have shown up in interest spreads in any statistically significant way. What is needed is a comprehensive theoretical framework that would spell out the various testable implications of the different interpretations. For that we need to be much more careful than in the past about the money-supply process.

Policy implications

The indicator models that show information content in the monetary aggregates do not in themselves have any policy implications unless one is willing to impose a particular theoretical framework on their interpretation. They do, however, rule out certain theoretical hypotheses and, in particular, they argue against a presumption that has guided much of the Bank of Canada's policy in the past. Specifically, they rule out the hypothesis that, on average, when the money supply is higher than predicted by a demand-for-money equation, this represents the effects of a pure shift in liquidity preference that is being accommodated by monetary policy and which, because it is being accommodated, will have no effect on aggregate demand for goods and services. In IS-LM terms, the shock is not just a latent displacement of the LM curve that is being offset by monetary policy. If that were the case, then there would be no reason to expect the observed systematic tendency for output and the price level to be higher in the future than one would otherwise have predicted on the basis of past values of output and the price level.

In this sense, the evidence undermines the presumption that a positive residual in the demand-for-money equation should be accommodated in the interests of stabilizing aggregate spending. This presumption has motivated a lot of Bank of Canada policy in the past, including the Bank's revealed preference for smoothing interest rate fluctuations in the short run, and its interpretation of the 1983 shift in M2 velocity. The evidence shows that, on average, the Bank's policy of accommodation has allowed spending to rise systematically following a positive shock and to fall systematically following a negative shock.

This is not to say that pure money-demand shocks never occur, just that the Bank has erred in the past on the side of interpreting innovations in the money supply as pure money-demand shocks to be accommodated with a change in the rate of monetary expansion, rather than interpreting them as money-supply shocks or as byproducts of aggregate demand shocks, which should call for a non-accommodative stance for monetary policy. Perhaps there is another interpretation of these shocks - other than the refuted one of a pure money-demand shock - which would also rationalize the Bank's tendency to accommodate, but I would like to see it spelled out. Until then, it seems to me that the only sensible lesson to draw from these indicator models is that if there is a surprise increase or decrease in the money supply at a time when the Bank is trying to stabilize aggregate spending, then, as a general rule, the Bank should take immediate steps to reverse the change in the money supply - in order to offset what will otherwise be a change in the same direction in aggregate spending.

One final policy implication that has come out of our discussions concerns the usefulness of M1, the narrow definition of money. Instability in the demand for M1 in the late 1970s and early 1980s was great enough to undermine the program of monetary gradualism that used M1 as a target variable. However, the indicator models suggest that M1 still has considerable predictive power.

The informational content of M1 has also been borne out by some recent work by David Laidler and William Robson (1990),[1] who have shown that moving averages of M1 growth are very highly correlated with moving averages of inflation two years later.

These results suggest that the instability of M1 demand that showed up under monetary gradualism may have been a feature of the short-run dynamics of adjustment, with little effect on the long-run relationship between monetary expansion and inflation. This interpretation is consistent with the results of Robert Lucas (1988),[2] who has shown that the M1 demand function originally estimated for the United States in 1963 by Allan Meltzer still predicts remarkably well despite the fact that it fails all sorts of econometric stability tests. Taken together, these results imply that the Bank of Canada should be paying close attention to M1 despite the fact that its demand function proved to be unstable under monetary gradualism.

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[1] D.E.W. Laidler and W.B.P. Robson, "Mainly Money: The Cause of Canadian Inflation," *Inflation Monitor* 4, May 1990. Toronto: C.D. Howe Institute.

[2] R.E. Lucas Jr., "Money Demand in the United States: A Quantitative Review," in *Money, Cycles, and Exchange Rates: Essays in Honour of Allan H. Meltzer*, edited by K. Brunner and B.T. McCallum. Carnegie-Rochester Conference Series on Public Policy 29 (Autumn 1988): 137-167.

ROUND TABLE REMARKS

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by Pierre Fortin

I shall direct my comments to the three sessions, asking in each case: (i) what the major conclusions have been; (ii) what remains to be done; and (iii) what the policy implications are.

Session I: Demand for money (M2 and M2+)

Major conclusions

The first conclusion of this session is that M2 velocity either has a unit root or is stationary around a deterministic trend with a break in 1983. Second, estimated income elasticities seem to hang somewhere in the rather wide (0.5, 1.0) interval. Third, Francesco Caramazza, Doug Hostland and Kim McPhail show that if price homogeneity is imposed, then the error-correction models (ECMs) are misspecified and the unit root model is the true one. If our prior belief in price homogeneity is firm, then those ECMs must be rejected. This conclusion is, of course, premised on the hypothesis that we know how to model the long-run demand relationship. Fourth, there is agreement that M2 responds weakly, if at all, to interest rate differentials, especially in the long run.

What remains to be done?

First, we have to understand the nature of the 1983 break identified by Alain Paquet and Steve Ambler - whether it was temporary or permanent, and what its root causes were - because so much of our parametric understanding of money demand seems to depend on that single event. Was it, as Pierre Duguay suggested, the inflationary period of 1975-83 that was odd, with 1983-84 signalling a return to normal,[1] or was it something else? Basically, we ought to find an economic interpretation as opposed to a mere statistical description of the situation. Second, while I have no problems with excluding real wealth variables from a demand equation for transactions money (M1), the omission of such variables from demand equations for broader money (M2, M2+ etc.) leaves me very uncomfortable. The aggregate should be broken down into holdings of households and firms, with different regressors in the two cases. This could be the place to introduce credit-rationing variables, which are a major contender for an explanation of why nominal income is correlated with lagged money (as Allan Crawford keeps emphasizing). Third, we have got to expand our understanding of substitution beyond the CSB connection towards a systematic search for relevant rate-of-return differentials with other assets such as long-term domestic assets and foreign assets, and for supply-side effects, particularly originating from the housing market. Fourth, we should re-explore the demand for M1. Given the useful information M1 seems to contain for fluctuations in real GDP, it would be very useful to find a reasonably stable M1 demand equation once the relevant financial innovations are accounted for.

Policy implications

First, the two papers imply that now is not the time to return to money targeting, either using M1 or M2. There are too many things not yet clearly understood, including how historical shocks to the money equations should be interpreted. The question of whether velocity should be modelled as a unit root or as a "stationary-around-something" phenomenon, has not been resolved in any satisfactory manner. Second, while M2 will probably remain insensitive to changes in the general level of interest rates, it will also continue to be subject to all sorts of substitution forces that are very difficult to interpret in the short run. For this reason, it will continue to be difficult for policy-makers to extract from M2 useful *leading* information on nominal GDP. M2-based information should be handled with care, even when used only as a guide to policy.

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[1] Duguay's conjecture would actually be consistent with the notion of forgetfulness developed by Maurice Allais in "A Restatement of the Quantity Theory of Money," *American Economic Review* 56 (December 1966): 1123-1157.

Session II: Indicator models

Major conclusions

The first conclusion comes from Patrice Muller's paper: real M1 is the best leading indicator of real GDP, and M2 bears a similar relation to the GDP deflator. In other words, the monetary aggregates contain a modest core of useful information. The second conclusion is derived from the Racette-Raynauld paper: the BVAR method offers a useful compromise between atheoretical VAR models and structural models. The great promise BVAR models make for the future is to filter short-run information on a large number of relevant variables in such a way as to maximize predictive performance. Third, Racette and Raynauld have shown convincingly that accounting for international influences greatly improves the forecasting accuracy of indicator models.

What remains to be done?

BVAR models should be better specified and made more operational. First, better BVAR models will come from imposing new constraints, relaxing some others, modifying the list of endogenous variables, introducing *Canadian* exogenous variables, (e.g., demographic, micro policy, etc.) and by experimenting with the Wiener filter.[2] Second, BVAR models will be made operational and useful only if their underlying economic and econometric structure is better explained and if a user-friendly protocol for the quarterly update of forecasts is developed. Otherwise, the method will not outlast Ronsard's rose ("*l'espace d'un matin*").

Policy implications

The most important conclusion here is that, among relatively simple methods of improving predictive performance, the BVAR approach should be a prime candidate. It gathers information on variables that are widely thought to be important, and it filters this information so as to get the "best bang per buck." It contains an embryo of understandable economic structure linking the variables to be forecast jointly, which has the potential to make it widely acceptable. Second, the method also has a potential for policy analysis as well as for forecasting. It would be possible to introduce into BVAR models a generic policy reaction function that could then be used to make forecasts conditional on the values chosen for the parameters.

Session III: Reconciliation

Major conclusions

The first conclusion concerns one of the central questions posed to seminar participants: Why do lagged monetary aggregates add to the predictive performance of an income equation that already includes lagged interest rates and lagged income as regressors? There is no dearth of sensible answers, alternatively based on reaction functions, on credit rationing, on the generating process for permanent income (Allan Crawford), on errors in variables, on complex lead and lag patterns (Gregor Smith), and on the accumulation of several omitted biases (Daniel Racette and Jacques Raynauld).[3] Second, none of the answers requires that we abandon the mainstream view of the channels of monetary policy, with interest rates playing a major role and credit constraints at times acting in a nonlinear fashion. There is no reason to jump onto the classical bandwagon, which argues either that money is essentially an endogenous response to income (in the real business cycle version), or that "anticipated" money has no effect on income (in the now-outmoded Lucas version).

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[2] I do have a problem with Racette and Raynauld's tendency to present the BVAR approach as structurally uncommitted. Those models do impose structure, as do even so-called atheoretical VAR models.

What remains to be done?

The session has produced a research program to look for factors likely responsible for the correlation between lagged money and current income. I would concentrate on identifying the structural model that gives rise to the correlation, and emphasize economic, as opposed to purely statistical, explanations.[4] In other words, I would recommend including in indicator models a number of interesting variables that have been left out (mainly credit-rationing, and domestic and foreign exogenous variables), and checking *ex post* how their omission influences the sign, level and stability of the estimated coefficients for lagged money. Of course, the greater the number of included variables, the less useful the indicator models are for timely identification of coincident or future cyclical developments. However, for policy-makers to avoid being misled, it is crucial to have an idea of the stability of the estimated coefficients of the included variables when relevant variables are excluded from the equation.

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[3] There are very few macro variables that are not correlated with lagged money!

[4] Much of the currently fashionable time-series econometrics can hardly be distinguished from the old practice of "measurement without theory" long ago stigmatized by Koopmans. This would lead us nowhere.

Policy implications

The first implication for policy is, in a sense, reassuring: the Bank should not be too worried about the validity of its traditional view of the transmission mechanism. Second, the Bank is right to continue to believe that monetary and credit aggregates contain a certain amount of useful information for the coincident and future behaviour of income. However, it should not rely on any mechanical relation between money, credit and income. Substitution effects, financial innovations and parameter shifts make the relations unreliable over the medium term. Handle with care. The key messages for central bankers are still: look at everything, don't overreact and remain flexible.

Central bankers have basically two questions to resolve: which nominal income target to pursue, and how to pursue it. This seminar has dealt with the second question. The conclusions, I think, are supportive of the Bank of Canada's mode of operation. I hope a future seminar will tackle the first question, which is by far the more exciting.

ROUND TABLE REMARKS

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by Charles Freedman

Let me begin with a few comments on the issue of whether money is demand-determined or not. In most textbooks on monetary economics, it is postulated that money is basically supply-determined. Typically, it is assumed that central banks set the level or growth rate of money *directly*, and this influences the path for interest rates and the exchange rate. Movements in interest rates and the exchange rate, in turn, affect the growth of spending and, with a lag, the rate of increase in prices.

Although perfectly adequate as a device for teaching monetary economics, this paradigm does not correctly represent the order of events in the "real world." In fact, the Bank of Canada has direct control only over its own balance sheet. In adjusting its balance sheet (typically, via drawdowns or redeposits of Receiver-General balances in the short run), the Bank changes the amount of settlement balances available to direct clearers. This results in movements in very short-term interest rates which, in turn, radiate out to the whole spectrum of interest rates and rates of return as well as to the exchange rate. As in the textbook story, these developments lead to changes in spending and, thereafter, in the rate of inflation. The various monetary and credit aggregates are influenced by the interest rate changes as well as by changes in spending and prices and, hence, are demand-determined. This is not to say that the monetary and credit aggregates are unimportant. Indeed, movements in these measures are closely associated in the long run with inflationary developments and they can play a very useful role as intermediate targets or information variables in helping to bring down the rate of inflation and achieve price stability. Nonetheless, it is important to note that they are not under the *direct* control of the central bank.

An understanding of the dynamics of the various processes and linkages is important to the Bank of Canada as it monitors ongoing developments. In particular, the interpretation of the movements of the money and credit aggregates depends very much on the leads and lags between the movements of the financial aggregates and those of spending and inflation.

There are, of course, two rather different approaches to specifying these relationships - as was reflected in the first two sessions of this seminar. The traditional demand-for-money approach links the demand for monetary aggregates to earlier or contemporaneous developments in spending, prices and interest rates, as well as to other variables. In the case of M2, the latter include the differential between interest rates on bank deposits and those on other instruments as well as the quantity of Canada Savings Bonds outstanding. Dummy variables are also sometimes used to capture bouts of financial innovation that cannot otherwise be specified in the equations. In the second approach, attention is focussed on the leading-indicator properties of the financial aggregates for future developments in spending and inflation. This approach is astructural and involves the estimation of reduced-form equations or the analysis of the information content of the financial aggregates.

There thus exist two sets of equations linking financial aggregates and the underlying economic variables. The purpose of the third session of this seminar was to examine the ways in which the two sets of equations might be reconciled. More generally, it would be very helpful to be able to interpret the movements of the narrow and broad monetary aggregates and those of the credit aggregates in the context of both demand equations and reduced-form or information-variable approaches.

The importance of having a consistent and integrated approach to the interpretation of the movements of the financial aggregates can perhaps best be illustrated by an example. Consider a situation in which nominal spending was growing more rapidly than projected but this fact was not yet known because of the publication lag on the national accounts data. The rapid growth in spending might show up in errors in the projections of money demand which were based on estimates of current nominal spending. At the same time, the information approach would often signal upward movements in nominal spending on the basis of the growth of the aggregates. If both approaches were pointing in the same direction it would be very comforting, and it would provide a solid basis, along with other information on underlying developments, for monetary policy actions to be taken. However, if the two approaches were leading to different interpretations of economic developments or if movements of the various financial aggregates were pointing in different directions, the financial aggregates would be less helpful in serving as a basis for changes in monetary conditions.

This latter possibility is exacerbated by the fact that there have been periodic waves of financial innovation that have affected the financial aggregates and their linkages to spending. In the early part of the 1980s, for example, M1 grew very slowly in spite of continuing strong nominal spending growth and inflationary pressures. If policy had been based solely on M1, interest rates would have been reduced inappropriately. As it turned out, there were a number of innovations in the financial sector that were responsible for the slow growth of M1 during the period[1] and, at least for a time, M1 was not usable as a guide to policy.

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[1] C. Freedman, "Financial Innovation in Canada: Causes and Consequences," *American Economic Review* (May 1983): 101-106.

The events of the last couple of years provide a more recent and practical example of the role played by the various aggregates in interpreting economic developments. Over the period since 1987, M2 and the credit aggregates have been growing very rapidly while the narrow monetary aggregate, M1, has been decelerating. From the demand-equation approach, the explanation of the divergent behaviour of the monetary aggregates rests primarily on the rising interest rates over the period, which influence M1 much more than the broader aggregates. In addition, there were periodic CSB effects (which influence M2) and some other special factors.[2] Using the information-variable approach over this period indicated some deceleration of real spending (from M1) along with increasing inflationary pressures (from M2 and some of the credit aggregates).

A complete reconciliation of the two approaches would involve two key elements. The first is an interpretation of the presence of particular variables in the indicator equations and the absence of others. For example, should money appear in the indicator equation once interest rates and exchange rates are introduced as explanatory variables? The second is an assessment of whether the lag structures and coefficient sizes in the two types of equation are consistent, taking into account the lag structures and coefficients in plausible equations for the rest of the economic system. A complete assessment would look at the equations for both narrow aggregates and broad aggregates. In the rest of my remarks I focus on the first issue, namely the interpretation of the presence and absence of variables in the indicator equation.

The simplest and most obvious way of interpreting the indicator equation and reconciling it with the demand-for-money equation is to solve the money-demand equation and the goods-market equilibrium equation (i.e., LM and IS curves) to yield the reduced-form equation in which nominal spending is a function of money. One implication of this way of resolving the issue is that, in principle, when interest rates are introduced into the estimated reduced-form equation they should drive out the monetary aggregate variable. Although this seems to occur in some U.S. equations,[3] it does not happen in Canadian indicator models, where either the money term dominates the interest rate term or it coexists with it.

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[2] It is also worth noting that the trend growth of the broader aggregates is higher than that of M1, as evidenced by the large constant in M2 and M2+ equations in growth-rate terms.

A second possibility is that suggested by Crawford, in which, because of the central bank reaction function, interest rates respond directly to movements in monetary aggregates relative to their targets. Although this approach is theoretically coherent, I do not feel that it offers a convincing explanation for the presence of both money and interest rates in the indicator models over the estimation period. It certainly was the case that the position of M1 relative to its target band played a role in the movements of short-term interest rates in the period between 1975 and 1981, although even then other factors played a role as well. But in the period before 1975 and that after 1981, it is hard to argue that M1 could account for any significant part of interest rate developments. Since the indicator equations suggest that the long-run relationship between the monetary aggregates and spending or inflation was about the same for all the various subperiods, it seems unlikely that the reaction function approach can offer much help in reconciling the demand-for-money equations and the reduced-form equations.

Another potential interpretation is based on the possibility that variables that have been omitted from the reduced-form equations or indicator models are correlated with the monetary aggregates and hence account for their significance. What sort of variables are likely to have been omitted? And if one can specify them why not introduce them directly into the equation? Two likely candidates stand out. The first is credit. But when credit is added to the indicator model, both money and credit tend to remain significant and the credit variable does not drive out the money variable. The second involves international variables. One of the interesting points from Racette and Raynauld's BVAR results is that one should perhaps pay more attention to the international variables in the context of indicator models.

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[3] C.A. Sims, "Comparison of Interwar and Postwar Business Cycles: Monetarism Reconsidered," *American Economic Review* (May 1980): 250-257.

Yet another possible way of reconciling the two sets of equations involves the existence of nonlinearities. If the world were truly linear, the reduced-form equation for spending would be expected to be a function of interest rates and the exchange rate, with no independent role for money. But if any of the equations in the system is nonlinear, it is no longer possible to solve the system for a simple, linear reduced-form equation. And in such circumstances, a linear approximation to a nonlinear solution might well include a money term. It seems to me that this is a promising avenue for research, and one that might explain in a more satisfactory way some of the empirical results that have been obtained.

I would now like to turn to the disequilibrium money story, as expounded by Laidler and Howitt, among others. This is not a view that I find particularly helpful or convincing, in large part because of the necessity in this approach for the supply of money to be independent of the demand for money. However, one could perhaps interpret the approach in a way that is more consistent with the notion that money is demand-determined.

Suppose that there is an aggregate demand shock to the system in the form of an exogenous increase in the demand for goods by households or businesses. If the latter borrow from banks to finance some or all of their increase in desired expenditures,[4] bank credit growth will rise in one form or another. The credit growth may be contemporaneous or leading with respect to spending. It will likely be contemporaneous in terms of the first round of expenditures since drawdowns of loans are today usually made at or just before the time of the expenditure, not much in advance. However, it may be leading in terms of the induced second round of expenditures resulting from the shock, i.e., the usual multiplier-accelerator type of response.

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[4] Of course, in Canada's very developed financial system there are many other ways of funding expenditures beyond borrowing from the banks.

What do banks do in response to a rise in credit demand? Typically, they raise deposit rates slightly relative to other rates to attract deposits to fund the increased loans, bringing about an increase in M3 if the funding comes from wholesale (non-personal) deposits, or an increase in both M2 and M3 if it comes from personal deposits. If there were perfectly articulated demand equations for M2 and M3, it would be possible to track these developments by focussing on the effects of changes in differentials between deposit rates of interest and competing rates of interest. In fact, it is very hard to pin down the coefficient on the interest rate differential with any precision. And good empirical equations for determining the setting of deposit rates by the banks are not available. Given our inability to track this type of change in money demand very closely, the quantity of M2 and/or M3 can be used as a proxy for what is happening to credit and spending.

One problem with this interpretation of the disequilibrium money story is that it suggests that credit should be a better proxy for spending than money and, hence, credit should drive out money in the indicator model. In fact, as mentioned earlier, this is not what happens in the estimated equations. However, one could argue that for the second-round spending effects, money might be more closely linked with spending than is credit, in which case both credit and money might play a role in the indicator models. In any event, some such interpretation may be helpful in reconciling the disequilibrium money story with a more traditional view based on money-demand equations.

ROUND TABLE REMARKS

General Discussion

Peter Howitt commented that the "disequilibrium" story for why money has a significant effect in indicator models is virtually the same as the "missing variables" story in the sense that, if equilibrium is not observed, some variable that affects money demand but is not modelled has changed. He noted further that the monetary variable in indicator models could be picking up the effects of many omitted variables. Such variables are likely to affect spending in different ways, however, and it is thus unlikely that one could find one single omitted variable that would be statistically significant and drive money out of the indicator models.

In response to earlier discussion of the influence of supply-side elements in the evolution of M2 and M2+, Charles Freedman re-emphasized his view that those aggregates are essentially demand-determined. He noted that, while the long-term goal of monetary policy is to bring down the rate of inflation and achieve price stability, the monetary aggregates can play a very useful complementary role as information variables (or, at times, as intermediate targets) to assist in achieving the long-term goal. In practice, if the monetary aggregates are growing too rapidly and other information confirms that there are actual or potential inflationary pressures, the Bank takes action to encourage a tightening of monetary conditions. The rise in very short-term interest rates that are most sensitive to Bank actions radiates out to market rates of interest along part or all of the maturity spectrum and tends to influence the exchange rate as well. Movements in interest rates and the exchange rate affect spending and prices. Along the way, these changes influence the monetary aggregates, either directly, as is especially the case with M1, which is quite interest-elastic, or indirectly, via their effect on spending and prices. In terms of the lag structure, the effects of Bank of Canada actions are likely to show up first in M1, then in real spending, then in the broader monetary aggregates, and then in prices. He added that, in achieving the ultimate goal of containing and reducing inflation, M1 may well be subject to rather sharp fluctuations because of its sensitivity to interest rates.

Regarding Howitt's comment concerning the "drift" in money, Pierre Duguay said he felt that it is very important to know whether money is drifting because spending is drifting (in which case one would not want to accommodate the drift) or because of a shock to money demand unrelated to income (that should be accommodated). In reduced-form models such as indicator models, it is difficult to distinguish between these two influences and, moreover, indicator models suggest that *both* money-demand errors and predicted money affect future spending. Modelling money demand is one way to distinguish between money-demand shocks and movements in money related to spending.

Returning to the idea that nonlinearities may account for the influence of money and credit in indicator models, Duguay proposed an alternative explanation: money and credit are picking up the effects of movements in the exchange rate - a variable which, in a small open economy such as Canada's, is one of the key channels through which monetary policy affects the economy.

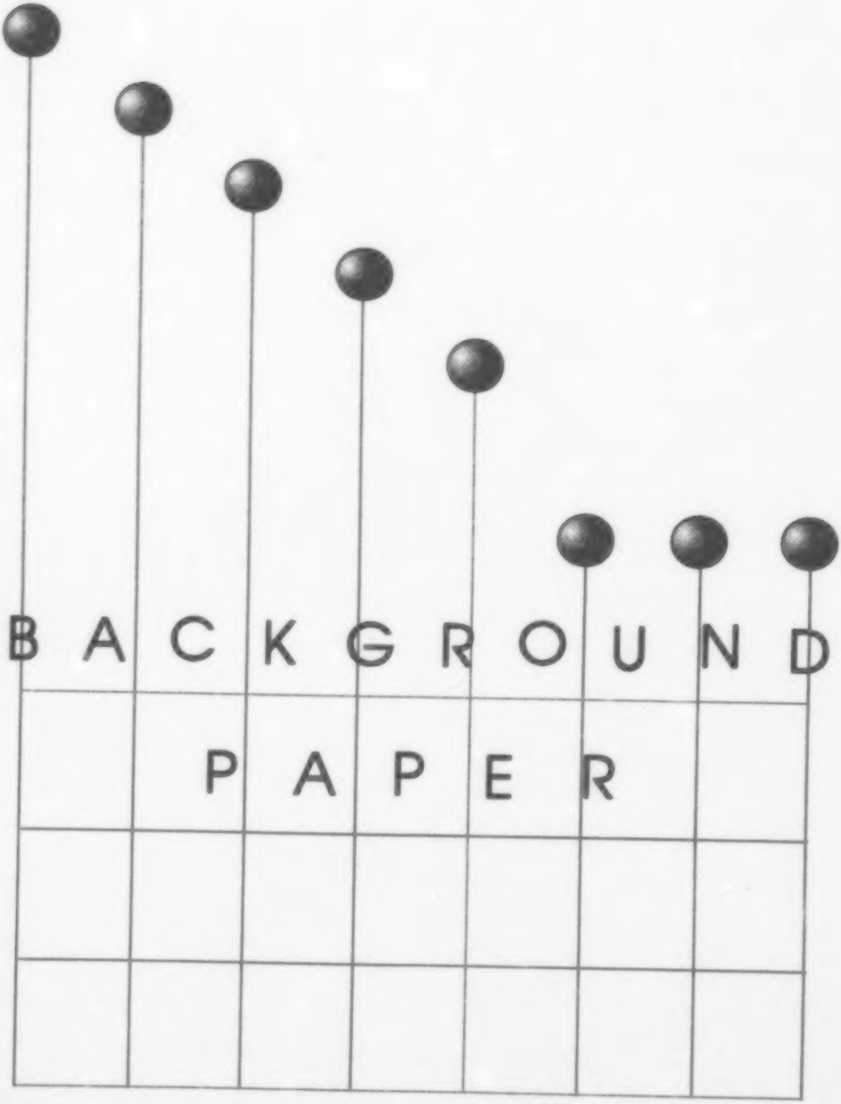
Daniel Racette noted that he was dissatisfied with the "checklist" approach to monetary policy. He argued that preliminary releases of data for many indicators on the checklist are frequently revised and may therefore give incorrect signals. He suggested that a much shorter "checklist" would be appropriate - one in which the exchange rate played a role and in which a monetary aggregate played a major role.

Charles Freedman re-emphasized the position he had taken earlier, that because of disturbances that cause a certain amount of random volatility in the money and credit aggregates, because of the dynamics involved, and because of the ever-present possibility of financial innovations, the Bank keeps an eye on a number of monetary and credit aggregates. The movements of the various aggregates help to interpret developments in the economy that impinge on spending and inflation. If all the aggregates are giving the same message, the interpretation is straightforward. But if there are conflicting messages, it is essential to assess any special factors that may be affecting the growth of particular measures. Ultimately, in a world with uncertainty, one filters all available information since it is rarely the case that all the information gives the same message, especially when the economy is near a turning point. Of course, special attention is paid to the nominal variables, most notably the financial aggregates, because of their role in helping monetary policy to avoid cumulative one-way errors.

Freedman added that the checklist approach was not adopted in order to give a *wider* scope for monetary policy but, on the contrary, was an explicit attempt to pin policy down, by focussing on *nominal* variables and avoiding the temptation to target on *real* variables. He noted that in order to adopt a single monetary aggregate as a target, one must be confident that its relationship is stable; otherwise, if the Bank has to abandon the target because the relationship involving the aggregate has shifted, or explain to the public why it is not moving the aggregate back towards the target in response to such a shift, monetary policy will lose credibility. Freedman said that he did not feel that a single or even a few variables were sufficiently reliable for the Bank to focus exclusively on them.

Paul Boothe commented that the Bank of Canada's goal of price stability was widely viewed as credible, but that economic agents were uncertain as to *how* the bank would achieve that goal. He advocated that the Bank be more explicit in describing how it planned to attain the objective of price stability.

Freedman remarked that it is important to reconcile the money-demand and indicator-model interpretations of the data because not only prediction but also explanation of economic events is important.



BACKGROUND PAPER

INSTITUTIONAL DEVELOPMENTS AFFECTING MONETARY AGGREGATES

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by Ed Fine

Introduction

Innovations in financial markets and in the deposit instruments offered by financial institutions had a major impact on the monetary aggregates in the late 1970s and the 1980s. As a result, the econometric relationship of money to income and interest rates was disturbed. In part, because of these innovations and our inability to predict fully the impact of such changes on the monetary aggregates, M1 was abandoned as a policy variable in 1982. Further developments in the 1980s have continued to affect various components of the monetary aggregates, particularly personal deposits.

In the late 1970s and early 1980s the pace of innovation in Canada's financial services industry quickened. In response to high and variable inflation, commercial customers started using more sophisticated techniques to manage their cash flows and demanded a wider range of services from their banks. Many of these customers had access to international markets and were aware of cash management packages being offered by banks in the United States. At the same time, technological improvements enabled the banks to track the costs associated with their services more closely, and to price these products accordingly.

Retail banking has been similarly affected by technological advances that enable the banks to segment more finely the markets in which they operate. Thus, the introduction of daily interest chequing-savings accounts, which were initially promoted by some banks as "all-in-one" accounts meant to replace separate chequing and savings accounts, was soon followed by a number of daily interest accounts, each with different interest rate tiers and schedules of service charges. The spread of automated banking machines (ABMs) in the 1980s increased the accessibility to bank accounts, allowing customers to make maximum use of daily interest accounts. However, it would be a mistake to attribute these innovations to technology alone; in most cases, the driving force was the pressure of competition among banks and from other deposit-taking institutions.[1]

What follows is a general overview of the major innovations affecting the monetary aggregates as they have been measured in Canada. Since the dates on which new types of accounts or services appeared at individual banks vary (and in many cases the changes are ongoing), it is often difficult to provide a precise date on which a particular development had its impact on the aggregates.

1. Innovations in Corporate and Commercial Banking

1.1 New cash management facilities

Beginning around the mid-1970s, large national corporations began to demand more sophisticated cash management facilities from their banks. These clients often had operations throughout the country, and (as technology advanced) wanted to forecast cash disbursements and receipts with some precision. Many corporations were developing sophisticated treasury departments and accessing capital markets both in Canada and abroad. They demanded facilities to consolidate their cash balances throughout the country at the end of each day in order to use funds more productively. At the same time, there was a need for greater transparency in banking arrangements. In general, customers preferred to pay for the banking services they used explicitly, and receive a return on their transactions balances.

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[1] See C. Freedman, "Financial Innovation in Canada: Causes and Consequences," *American Economic Review*, (May 1983): 101-106.

The banks responded by offering, on a fee basis, regional lock-box facilities providing for the consolidation of receipts through the banks' national branch networks. Fees for deposits and withdrawals were structured to account for the presence (or absence) of interest-free balances. In addition, as interest rates rose, the banks began to track the cost of float related to each client's business, and to recapture this cost either through fees or by demanding compensating balances in zero- or low-interest accounts.

In some cases, banks began to pay interest on current account balances. However, more often, they provided facilities to reduce current account balances to zero at day-end and employ the excess funds in overnight, or somewhat longer-term certificates of deposit (CDs). Typically, the yield was based on a spread below the bank prime lending rate, although if the funds were received late in the day, a very low rate (say, just 3 per cent) might apply.

This consolidation of balances also allowed customers with more sophisticated needs to employ their excess funds in money market instruments. This could be quite attractive if the funds were available for more than a few days, as the yield on 30-day commercial paper or treasury bills could be as much as a percentage point or more above the yield provided on CDs of the same term to maturity.

Implications for the monetary aggregates

This phase of cash management resulted in an overall economization of corporate transferable balances, affecting the narrow aggregate, M1, in a downward direction. As well, the deployment of excess cash into CDs resulted in some migration from current accounts included in M1, a shift that was internalized only in M3. The balances remaining in current accounts were generally more volatile, resulting in increased variation in M1.

1.2 New cash management accounts

As the use of cash management facilities spread, smaller companies began to demand better returns on their cash balances. These companies did not adopt the sophisticated treasury management techniques used by larger corporations, but, as interest rates rose to record levels in the early 1980s, their financial officers became keenly aware of the cost of idle cash. Around this time, the definition of "notice" for purposes of reserves was being clarified with the result that the banks were able to create a new breed of chequing account and classify these as "notice" for reserve purposes.[2] As a result of the lower reserve requirements that applied to these accounts (3 per cent at the large banks compared to 10 per cent for demand deposits), banks were able to offer somewhat more attractive interest rates.

The banks began to offer interest-bearing chequable notice accounts to companies around 1982. The interest rates paid on these accounts vary from customer to customer, and are based on the client's profile of deposits and cheques, with particular attention to the float generated by its transactions. The rate is generally negotiated as a spread below the prime lending rate. The accounts are classified as non-personal chequable deposits, and are included in M2, but not in M1.

Implications for the monetary aggregates

The advent of notice accounts resulted in a further migration from current accounts to non-personal notice deposits, causing a downward shift in

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[2] In order to be reservable as a notice deposit, a bank must indicate it has the *right to require notice* of withdrawal. In practice, notice is seldom, if ever, demanded and companies are free to write cheques on these accounts.

M1. Many existing clients with cash management facilities consolidated their current account-cum-CDs into these new accounts. This contributed to the shift out of M1, while the proliferation of notice accounts resulted in an upward shift in M2. Only in the broadest bank aggregate, M3, were these shifts internalized. Thus, the transactions component of M2 was unchanged, and the deposit balances remaining in M1 were increasingly weighted towards those of small businesses.

2. Innovations in Retail Banking

2.1 Daily interest savings accounts (DISAs)

The Bank of British Columbia and some credit unions had offered daily interest savings accounts (DISAs) since the mid-1960s. When the Continental Bank began operations in June of 1979 it offered daily interest accounts to individuals, and Canada Trust introduced a similar account soon afterwards. In August 1979, the Bank of Montreal became the first bank to offer DISAs nationwide and, by the following month, the other four major banks were also offering them. National Bank introduced its DISA in December 1979.

Some banks initially charged high fees (50¢ or $1) for withdrawals, which could only be effected at the counter. This reduced the usefulness of the daily interest account as a substitute for personal chequing accounts (PCAs). Initially, interest was credited semi-annually at most banks, as was the case for other savings deposits. However, in an innovative move, the Royal Bank began crediting interest on a monthly basis in 1980. In April 1981, the Bank of Montreal followed suit, as did the Toronto Dominion and Continental in July. By early 1982, all banks except the Bank of Nova Scotia and the National paid interest on a monthly basis. The monthly-pay accounts paid lower interest rates (by about 50 basis points) than semi-annual-pay accounts.

Implications for the monetary aggregates

Initially, the shift into DISAs was mainly from other savings deposits, primarily other non-chequable deposits. However, there were also inflows from fixed-term deposits, especially at times when interest rates were volatile. Nevertheless, despite the inconvenience of branch withdrawals, there is evidence in the early years of some shift from PCAs, perhaps as much as 1.5 per cent of M1. As banks eliminated their withdrawal fees and introduced automated banking machines (ABMs), the DISA became an even more attractive instrument for transactions purposes.

In addition to a shift out of M1 (which was internalized in M2), there was migration back and forth between deposits at banks and non-banks as the pace of innovation varied both by individual financial institution, and by type of institution. For the most part, these shifts were internalized within M2+.

2.2 ABMs

In the early 1980s, as interest rates rose to record levels, customers were induced to increase the number of transfers between PCAs and DISAs. Combined with technological advances, the economics of investing in ABMs became more favourable to financial institutions, and there was a virtual explosion in the number of machines.

Implications for the monetary aggregates

Easier access to deposits would be expected to lead to reduction in cash holdings by individuals, especially when their deposits accumulate interest on daily balances. However, this effect has been hard to measure.

2.3 Daily interest chequing accounts (DICAs)

The Bank of British Columbia was again an innovator when it introduced the first daily interest chequing account (DICA) in 1977. Canada Trust followed in 1979, and the first nationwide bank DICA was offered by the Bank of Montreal in April 1980. Owing to technological constraints, the other major banks did not introduce DICAs until 1981 and 1982. Initially, the banks paid 3 per cent on all such balances. However, the Toronto Dominion introduced a tiered account in January 1981, which was the first "all-in-one" account - an account that combined chequing features with a savings account rate of interest on balances above $2,000. Most other banks followed suit with their versions in 1982. The Bank of Montreal became the last bank to offer a tiered structure in November 1985. As was the case with the first DICA, technological ability was a major factor in the pace of competitive innovation.

With the tiered account, interest rates were 3 per cent on the first tranche, typically $2,000, and the banks added to the number of tiers over time until the top tranche paid a rate comparable to the rate on 90-day personal fixed-term deposits. Banks offered no-charge chequing if customers maintained a minimum monthly balance above a certain amount, initially $200. Some banks returned cheques for an extra charge; most banks used the new account to promote "cheque truncation" at the branch level; this avoided the costs associated with sorting and returning cheques each month. The fine segmentation of retail markets is reflected in the fact that some banks offer two DICAs with different tiers and schedules of charges aimed at different markets.

Implications for the monetary aggregates

Initially, the main source of DICA growth was from DISAs and PCAs. There was also a minor shift out of personal term deposits as the banks introduced tiers paying progressively higher rates. The shifts from DISAs and term deposits resulted in an upward movement in M1A,[3] although they were internalized within M2+. There were, however, shifts into and out of M2 as the pace of innovation was again uneven at financial institutions. Banks aggressively promoted DICAs and gained market share from the trust and mortgage loan companies (TMLs), except for Canada Trust, between 1984 and 1986. This was reflected in the growth of M2.

2.4 High-balance DISAs (treasury bill accounts)

In October 1985, Toronto Dominion introduced the "investor" account, a tiered DISA paying progressively higher yields on higher balances. Canada Trust followed in December 1985, and by mid-1987, the five major banks offered high-balance DISAs.[4] The yields on the highest tranches are comparable to those on treasury bills, and the TMLs marketed the accounts as "treasury bill" accounts. In some cases, the top rate is paid on the entire balance; in others, on incremental balances only. Usually, customers are offered two free cheques per month and are charged $1.25 per cheque thereafter. Since these accounts are not suitable as transactions accounts, they are classified as non-chequable personal savings deposits.

Implications for the monetary aggregates

To the extent that some of the growth that occurred in high-balance DISAs came from Canada Savings Bonds or money market instruments such as treasury bills, all the monetary aggregates were affected. However, initially at least, the main source of funds to these accounts appeared to be from DICAs, other DISAs and personal fixed-term deposits. Thus, most of the shifts were internalized in M2+. There were, of course, shifts into and out of M2 as the pace of financial innovation differed across institutions. More than half the dollar value of these accounts is held in balances over $60,000, suggesting a customer base that would be rather sensitive to interest rate changes. Whether this results in an increased sensitivity of the entire aggregate M2 (or M2+) to interest rates is a moot point.

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[3] M1A was introduced in March 1983 in an attempt to measure balances held for purposes of making payments under these new institutional arrangements. In addition to M1, it includes all daily interest chequable deposits and non-personal notice deposits.

[4] The National Bank introduced a high-balance account that offered free chequing if the minimum monthly balance exceeded $10,000. The charges for cheques issued on lower balances were comparable to those on PCAs. As this account was functionally used as a transactions account, it was classified as a DICA.

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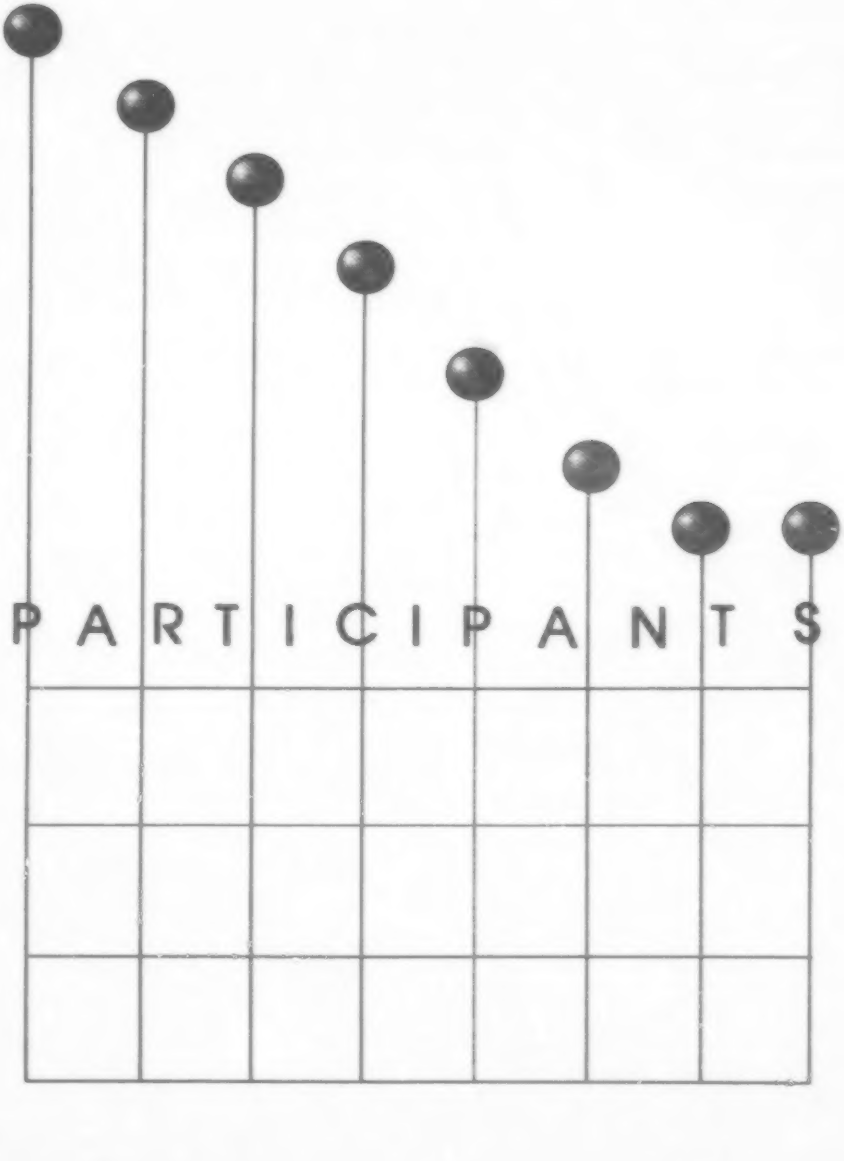

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